THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. XIX.—*On the Existence in both Hemispheres of a Dry Zone, and its cause;* by ARNOLD GUYOT.

(Read before the National Academy of Science, Nov., 1882.)

OF the two elements of climate indispensable to vegetable and animal life, temperature and moisture, it is well known that the distribution of the latter is subject to the greatest irregularities. While the average annual temperature in each place varies but a few degrees, from year to year, the quantity of rain at the same place may differ from one year to the other by one quarter or even one half. In tropical countries where the temperature is almost constant, the quantity of aqueous precipitation shows the greatest extremes; for here we find both the rainless districts as well as the most abundantly watered regions. These irregularities render it all the more desirable that some general law should be found which may aid us in putting order in this apparent disorder, and in understanding the causes of these extraordinary variations.

One of the general laws already recognized is that the quantity of rain, on the whole, decreases with the temperature, that is, from the equatorial belt toward the poles. This was to be expected since the warmer the air the greater is its capacity for holding vapor. If the average quantity of rain within the tropics is from 90 to 100 inches, it is only 60 on the 30th parallel, 40 on the 40th parallel, 20 on the 50th parallel, 10 and less in the polar regions. This general law, however. experiences a remarkable interruption a little beyond either tropic, where the quantity of rain is suddenly reduced to a minimum, while on the equatorial side of that belt we find the

abundant summer rains of the tropical climate, and on the polar side the copious winter rains of the warm temperate regions. The result of this scarcity of rain, in these particular latitudes, is apparent in the existence of a series of dry lands which, nearly all, are among those enumerated in the paper of Professor Loomis, just read, as having a fall of rain below 10 inches. (See this Journal, Jan., 1883.) I have shown elsewhere —in my Physical Geography, page 90—that these dry, parched tracts form two belts around the globe; two *dry Zones*, on both sides of the tropics, containing most of the so-called deserts of the world, in which the regime of the rains, as well as their quantity, differs from that of the neighboring climatic regions. As this fact, however, does not seem to have been fully recognized, perhaps for the want of a sufficient development, I beg leave to again call the attention of the Academy to it, and to indicate in a few words, what I believe to be the cause to which this remarkable phenomenon may be referred.

The Northern zone of dry lands extends in width from about 24° to 32° N. lat. (See Loomis's map of rains, in this Journal, vol. xxv, January, 1883). In the New World it begins at the west with the peninsula of Lower California; thence passing through Arizona, New Mexico and Western Texas. In all these lands, extending for nearly a thousand miles from west to east, the annual fall of rain remains below ten inches, and goes down to two and three inches, while in some years the rain fails entirely. Farther east, in the same latitudes, local causes, to be mentioned hereafter, give abundant rains to the valley of the Mississippi and Florida.

In the Old World the dry zone occupies the very center of the Great Sahara, where the absence of rain is nearly complete on a length of 3,200 miles, and is considerably increased in width. Thence it crosses the central part of Arabia on a line of 1300 miles, passes through the dry plateau of Eastern Persia and Beloochistan, and reaches, beyond the Indus, the desert of Thurr, after a course of another one thousand miles, making together a tract of 5,500 miles of dry lands.

Farther east, as in the New World, local causes bring, in the same latitudes, abundant rains which mask the influence of the general cause of dryness, as it will presently be shown.

In the Southern hemisphere the dry zone is strongly marked on the west slope of the Andes. It is well known that all the coast of Peru from Punta Parina 6° S. L. to N. Chili 30° S. L. is a rainless region; but it would be a mistake to believe that the atmosphere is wanting in moisture in all that extensive district. All along the Peruvian coast, though owing to special circumstances, no condensation takes place near the seashore sufficient to produce rain, the thick winter fog, called the

Garua, furnishes moisture enough to render all hills and pastures green with verdure. In the latitude of the dry zone, however, from 20° to 30° S. lat., in the desert of Atacama, about the tropic of Capricorn the atmosphere is not only rainless but perfectly dry. Even on the coast of Chili, Copiapo, 27° S. lat., receives only 0·32 inch of rain, La Serena in Chili 0·5 inches. In the same lat. on the east of the Andes the plains of the Pampas are subject to great droughts. The *gran-seco* (great drought) of nearly three years duration, which took place in this century, is still remembered as having cost the life of millions of cattle which came to die along the few river courses which had retained some water; leaving their bones accumulated just as the fossil bones of the Quaternary mammals are now found in the Pampas.

In the same latitudes in Africa the Kalahari Desert extends over the whole western half of the continent and beyond. In Australia the dry zone passes from west to east through the very center of the continent between the summer rains of the tropics and the winter rains of the more southern latitudes, with the exception of a narrow strip of the eastern coast which is watered by the winds from the sea; condensing rather scanty and irregular rains on the Blue Mountains and the Australian Alps.

The existence in each hemisphere of a dry zone in the subtropical latitudes may thus be considered as a fact for which a cause must be found. On the other hand it is true that both in the northern and southern hemispheres notable interruptions are found, and it is to be remarked that they are all on the eastern side of the continents. In America from eastern Texas along the gulf to Florida the latitude of the dry zone has an abundance of rains. In the Old World from the Sind desert near the Indus through both Indian peninsulas and Southern China, the lands in the latitudes of the dry zone are still more plentifully watered. In the southern hemisphere the eastern half of South America and South Africa and the eastern coast of Australia, though moderately supplied, are not wanting in rain, especially near the sea. This apparent anomaly also has to be accounted for.

As among the causes which govern the aqueous precipitation the course of the winds occupies the first place, I am inclined to think that a close consideration of the normal movement of the atmosphere in the latitudes of the dry zones will account for the above mentioned facts.

These winds belong to two classes. In the first are those which form a part of the general circulation of the atmosphere, resulting from the spherical form of the globe. In the other are winds mainly due to the relative distribution of continents

and oceans and participating therefore in the nature of the monsoons. To the first, I believe, the scarcity of rain in the dry zones must be attributed; to the others the abundance of rain in the well-watered portions of the same zones, which interrupt the continuity of the dry lands.

The operation of these causes is as follows:

It is generally accepted that the primary circulation of the atmosphere, arising from the difference of temperature between the tropical and the temperate and cold regions of the globe, has its origin in the broad ascending current which, under the influence of a powerful equatorial sun, starts from the belt of calms. This current carries incessantly into the upper regions of the atmosphere vast masses of air which overflow on both sides toward the temperate zones, causing an accumulation of air about the 30th degree of latitude, enhanced still more by the decrease of the areas poleward. This accumulation is shown by the existence of a belt of high barometric pressure, which there reaches the maximum known on the surface of the globe. From this belt of high pressure the air, as usual, divides, flowing downward both ways. A portion of the current returns toward the tropics and becomes a part—perhaps the main part—of the trade winds and reascends in the belt of calms, making a complete circuit, as well shown by our colleague, Prof. Ferrel. The second flows poleward and becomes the anti-trades and the southwesterly winds characteristic of the temperate zones. The part, however, which each of these bodies of winds plays in the condensation of rains is very unlike; the first brings drought; the second is the principal source of the rains of the temperate latitudes.

It may, at first sight, appear singular that these two branches of the same aerial current should have so different an effect on aqueous condensation. A moment's reflection, however, will make the reason clear and dispel our surprise. Both are descending currents; as such they will be dry winds; for a descending wind forced into a region of greater pressure will contract; in so doing the latent heat which it has absorbed in ascending, reappears and increases its temperature and capacity for moisture, thus rendering condensation more difficult, if not impossible. But when traveling farther, circumstances change. The equatorial branches blowing toward warmer regions, with no chance to meet a cooler atmosphere, lose all regular causes for condensation, and the countries they pass over remain dry and parched. The polar branches, however, traveling toward cooler latitudes, their relative humidity gradually increases at every step and rain will soon ensue.

Moreover both currents gradually diverging toward opposite quarters, before they reach the ground, leave between

them a neutral zone, where the motions of the air will be few and irregular, forming the sub-tropical calms, or horse latitudes, where ascending currents or cool winds, which might bring rains, are almost impossible. Wherever such conditions are found a *dry zone* is sure to appear. Thus the existence of dry zones in the latitudes above mentioned is not an accidental phenomenon, only due to local causes, but it depends upon the laws of the general circulation of the winds.

If it be so it is evident that modifications in that system will affect the position of the dry zones. The southern zone, for instance, is somewhat nearer the tropic for the reason that the middle, or central line, of the belt of calms is on the north of the equator, removing the whole system of trades and anti-trades toward the north, an effect due, no doubt, to the predominant extent of the land masses in the N. Hemisphere.

Though this cause of dryness in these particular latitudes may be considered as by far the most efficient, secondary causes are not wanting which intensify locally the phenomenon, or give it a greater extension. It is to be noted that most of these desert regions are plateaux, with the exception of the outskirts of the Sahara, the Indian desert (of Thurr) and central Australia. Plateaux always increase the dryness of the atmosphere above them for several reasons. Those usually given, such as their distance from the sea, the decrease in the supply of moisture owing to the condensing action of their border mountains, are no doubt efficient causes; but they are by no means the only ones. Perhaps one of the most active is the elevation above the sea level, into the continental atmosphere, of such large portions of the earth crust. Their surface exposed to the increased power of the rays of the sun, in a usually clear sky, with diminished density of the air, becomes strongly heated, keeping the air on the plateau warmer than the air at *the same level* above the neighboring sea or lowlands. It is evident that in such circumstances the moisture brought by cooler winds, blowing from the sea into the warmer atmosphere of the plateaux, will have no chance to condense, except on the mountain chains which may happen to break the monotony of their surface, as we see it in the vast plateau region between the Sierra Nevada and the Rocky Mountains.

The great scarcity, or even complete absence, of vegetation, the bare, or sandy soil, usually characteristic of the desert, favors in these subtropical latitudes an accumulation of heat which adds another element of dryness, and which tends to increase the breadth of the dry zone.

The rains, often quite abundant, which fall in the portions of the subtropical zones situated on the east side of the great land masses and which have been indicated above as notable

interruptions of the dry zones, are due, not to the general currents resulting from the spherical form of the globe, but to the powerful influence of the relative situation of the great land masses and water areas, producing strong monsoon winds. These monsoons are nowhere more marked than on the southeast portion of the huge mass of the Asiatic continent, where they overcome the general wind circulation, extending even far beyond the dry zone, as Woeikoff has shown, at least as far as Japan. In North America, owing to the triangular form of the continent, its largest portion is in the north. This extensive land area being overheated during the summer, the southwest returning trades are deflected during the warm season toward that region of greater heat and low pressure, and are changed into the south winds which prevail at this time in the valley of the Mississippi and bring from the warm waters of the Gulf and the southeast Atlantic the abundant vapors and the summer showers which greatly increase the average amount of rain in that region.

Thus is explained the anomaly observed in the eastern third of the continent of North America, namely that contrary to the usual law, the amount of rain on the same parallel instead of diminishing from the coast toward the interior, rather increases to a distance of a thousand miles from the sea-shore.

Only a few words more on the name of the different zones of rains mentioned in this paper. It has been usual, for a considerable time, to call the region of the winter rains the *subtropical* rain-zone. As these rains very often extend as far as the 40th parallel, as in California and elsewhere, while they do not reach the region of the alternate tropical summer rains, the name *subtropical* seems rather to be a misnomer; the dry zones, as above defined, are really the true sub-tropical zones. From the equator northward we would thus have 1st, the equatorial zone of daily rains; 2d, the zone of alternate tropical rains and dry seasons; 3d, the subtropical or dry zone; 4th, the zone of winter rains and dry summers proper to the warm temperate regions; 5th, the zone with prevailing equinoctial rains, or the temperate regions; 6th, the zone of prevailing summer rains and cloudiness, or the cold temperate region. Though these zones somewhat vary their position in latitude, according to local circumstances, they can always be recognized, and they agree with the average distribution of temperature and with the circulation of the winds.

ART. XX.—*On the Relations of Temperature to Glaciation;* by GEORGE F. BECKER.

THE theory of a Glacial period has always presented great difficulties. Agassiz acknowledged their existence from the first, and stated that his hypothesis seemed to conflict with the apparently well-established theory that the temperature of the earth is gradually and progressively sinking. His investigations led him to the belief that the decline in temperature was not uniform, but marked by the occurrence of repeated minima. Dr. Frankland, Baron Sartorius von Waltershausen, Mr. Clarence King and others have pointed out that to account for the enormous accumulation of ice during the Pleistocene, it seemed necessary to assume an evaporation much more active than that of the present day, and which could scarcely be accounted for except on the theory of the prevalence of higher temperatures. Prof. Whitney has lately advocated a similar view, while the general opinion among geologists has been that to account for the accumulation of ice in question, a lower temperature was requisite. This view has recently been sustained by Mr. G. K. Gilbert in opposition to the arguments presented by Prof. Whitney. Since it is evident that the question cannot be settled without further discussion, it is probably desirable to consider it from as many points of view as possible. Of these one will be here presented.

If the sun and earth are members of a system now undergoing a uniform loss of heat, it appears certain that the formation of glaciers must be limited to a distinct period in the earth's history. So long as the temperature nowhere sank, even during the winter months, as low as the freezing point, it is manifest that no glaciers could form. A moment's reflection will also show that a sufficient diminution of temperature on the earth's surface would preclude the formation of glacial ice, for the rate of evaporation diminishes more rapidly than the temperature. The entire quantity of water existing in saturated aqueous vapor at a temperature of minus 20° C. is a little less than would be precipitated from aqueous vapor of a temperature of plus 20° by a reduction of only a single degree. Since the precipitation must equal the evaporation, the snow-fall in the later stages of the history of the earth must therefore become infinitesimal. The present time lies between the extreme periods indicated, and it is known by observation that glaciers are in process of formation. It is certain, therefore, that the development of glaciers on a cooling earth, must increase to a certain maximum and again decline.

The formation of glaciers must be confined, under otherwise equal conditions, to areas lying between certain isotherms. If a mountain is supposed to rise in a tropical country to an indefinite height, a temperature will prevail at its foot too high to allow of the formation of ice, and its peak may be supposed to stand at an elevation where the cold is too great to permit of any considerable precipitation. Dr. Tyndall has drawn attention to this fact and pointed out that, were the mountains high enough, there would be an upper as well as a lower snow line. If the earth is a cooling body, this snow belt must gradually be descending the hypothetical mountain suggested, and localities once too warm for the formation of névé must subsequently have been occupied by this incipient form of glacial ice, and again have grown too cold to permit of its formation. It appears, therefore, that not only the general development of the glacial system of the earth, but individual glaciers must, upon the current hypothesis concerning the cooling of the solar system, pass through a maximum.

The prime condition for the formation of a glacier is the accumulation in a basin of a quantity of wet snow, greater than will melt in the course of the season. The overflow of this basin takes place in the form of the glacial stream, which descends to a lower level until a temperature is reached at which the melting is so accelerated that the combined fusion and evaporation reëstablish the equilibrium between dissipation and solid precipitation. As observations show that both the névé and the glacier maintain substantially a constant temperature, that of melting ice, it is clear that both fluid and frozen water are essential constituents, since otherwise the temperature must vary. This fact is also readily explained, for the conversion of snow to ice, as is well-known, takes place by regelation which, under ordinary pressures, occurs only at the freezing point. It is true that the melting point of ice is lowered by pressure, and consequently it is conceivable that snow cooled below zero should accumulate at a great elevation in such masses, that the pressure upon its lower surface would be sufficient to produce fusion and union of the frozen particles of ice. In nature, however, this process can scarcely go on except in the immediate neighborhood of the zero point, for long before a column of snow cooled even a single degree below zero would be sufficient to produce this effect,* either the pressure would be relieved by avalanches or the light dry powder would be blown away by the tremendous gales which

* According to Sir W. Thomson's experiments, and Prof. Clausius's computations (Clausius' Mech. Wärmetheorie, i, 172), a pressure of one atmosphere depresses the melting point of ice 0·00733° C. It follows that a pressure of about a ton per square inch, or many thousand feet of snow, would be required to reduce the temperature of fusion 1°.

prevail at great elevations during the winter months. A portion of the snow thus removed from the higher parts of the snow belt will lodge at lower levels in névé basins, and the snow falling upon these basins from the clouds at temperatures considerably below the mean will also in part be swept away, and not contribute to the mass of névé. The actual precipitation on a névé field is, therefore, not an accurate gauge of the frozen water which it receives.

While both snow and rain, or melted ice, are essential constituents of the névé, it is evident that the formation of the glacial ice will not be most rapid at the extreme lower edge of the snow belt, for if the heat received is more than sufficient to raise the frozen water to the temperature at which regelation is most easy, the excess of heat will produce further liquefaction, and diminish the accumulation. This, therefore, will be most rapid, and the resulting glaciers largest neither at the upper nor the lower limit of the snow belt, and, other conditions remaining equal, it appears certain that the maximum accumulation will take place along a certain isothermal line, the temperature of which will not in general be very far removed from zero, though its precise temperature will depend upon local circumstances, such as the average humidity; the shelter from the direct rays of the sun, the distribution of moisture through the year, etc.

As has already been seen, the formation of glaciers is dependent upon topographical, as well as meteorological conditions. In order therefore to institute a comparison between the tendencies to glacier formation at two given periods of the earth's history, it is convenient to begin by assuming entire similarity between the topographical characters of the areas covered by the snow belts at the two epochs. Suppose the surface under consideration to be substantially an inclined plane of limited width but of an indefinite extension upward, this surface being merely roughened by depressions suitable for the accumulation of névé. Suppose also the proportion of sunshine and the strength of the winds to be the same at the two periods, then during the warmer epoch the maximum tendency to glacial formation will exist along a higher line, and during the colder period along a lower line upon the inclined plane. Both of these lines will be horizontal, and their temperatures will be nearly the same. The question to be decided is upon which of them will glaciers form most rapidly.

The relations of temperature to elevation are known to be involved in much obscurity, the degree of heat varying not merely with the pressure (Poisson's law), but being affected by the irregular ascent of warm currents from the earth, by the liberation of heat attending the precipitation of rain and snow,

by topographical conditions, etc. The higher the temperature of any locality, however, the more rapidly the thermometer is found to fall as neighboring mountains are ascended. The rate of decrease of temperature with increasing altitude is greater in low latitudes than in high ones, and in one and the same locality is greater during summer than in winter, and greater during the warm hours of the day than before dawn.* This relation holds good even for very lofty elevations such as the summit of Pike's Peak, and there seems no reason to suppose that it does not extend over the snow belt. If so, the diminution of temperature with increasing altitude must have been at least a little greater in the snow belt of the warmer period than on that of the cooler period on the inclined plane supposed. Precipitation is mainly induced by the cooling of moist air as it rises along declivities, and, other things being equal, the precipitation will therefore be measured by the rate of diminution of temperature. It follows that the precipitation within a given distance of the line of maximum glacier formation of the warmer period, probably exceeded the precipitation within the same distance of the corresponding line in the cooler period.

The other conditions, however, would not be equal. Although the mean temperature of the air within the two belts might be identical, the heat of the direct sunshine would be more powerful during the warm period than at the later date, and consequently ice and snow exposed to the sunshine would melt more rapidly. Neither would the conditions at sea level be the same. Not merely would more heat be employed in evaporating water from the ocean during the warmer period, but the temperature of the ocean itself would be increased, especially near the surface, but also throughout the whole depth of shallow seas. As is well known, the rate of evaporation depends primarily upon the temperature of the surface of the water, and it follows immediately from the formulas which state the observed relations between temperature and tension of aqueous vapor, that the more intense the radiation from the sun, the greater will be the proportion of the heat employed in the evaporation of water. Appeal to observation shows that the operation of this law is not substantially obstructed by the action of any other of a contrary tendency. The heat received from the sun upon a square mile of the earth's surface, in latitude 45°, allowing for the absorption of the atmosphere, must be somewhat more than one half of the amount received upon an equal area at the equator, while the average rainfall of latitude 45° is only one-third of that at the equator. The rate of evaporation of still water in the two

* See Loomis's Meteorology, p. 40; Report of Chief Signal Officer, 1876, p. 348; and Professional papers Signal Service, II, Isothermal Lines of the U. S.

latitudes must differ considerably more than is thus indicated; for a large part of the moisture evaporated in the tropics rises many thousand feet above the surface and is carried poleward by the upper air-currents, while the surface of the sea in high latitudes owes a portion of its temperature to heat absorbed from the sun's rays near the equator. It is perhaps impossible in the present state of knowledge to make any exact comparison between the amounts of moisture reaching an elevation equal to that of the glacial line in the tropics and in higher latitudes, but enough is known to make it certain that the excess near the equator is very great, while the fact that, in spite of the transference of much of this vapor to the temperate zones, the snow line in the tropics reaches a lower isotherm than it does north or south of them, shows that the greater intensity of the sun heat above the snow line near the equator does not counterbalance the greater precipitation on the snow belt. Experience, therefore, amply justifies the statement that in the absence of meridional, oceanic and aërial currents, the effect of which will be considered later, the precipitation on the earlier and higher snow belt of the supposed inclined plane would exceed that upon the corresponding belt of a later and cooler era more than in proportion to the intensity of solar radiation.

The melting of ice at the glacial line, on the other hand, must be simply proportional to the heat received from the sun, since its temperature cannot be raised. Evaporation would be no greater during the warmer period, for supposing the air over the snow belts of the two periods to have the same temperature, that characteristic of the glacial isotherm, and that the saturation of the atmosphere were the same, the evaporation would of course remain unchanged. As has been shown, however, the rate of decrease of temperature, and the mean saturation, will probably be greater in the warmer period, and evaporation near the glacial isotherm will therefore be less.

If the inclined plane of limited width, considered in the foregoing paragraphs, also had a vertical limit, and if the sun has been gradually and uniformly cooling during the past, this slope can have had no glaciers until the lower snow line reached its upper edge. The maximum development of glaciers on this slope must have occurred when what has been called the glacial isotherm coincided with its upper edge, and since that time the magnitude of the glaciers upon the slope must have been constantly diminishing.*

* It is of course to be understood that simple glaciers only are referred to, i. e. that a single glacial stream is supposed to drain only a single névé basin. In point of fact a large glacier frequently drains many névé basins at various altitudes. Such a glacier on the hypothetical slope might remain of constant magnitude during a long period of time, the increase of accumulation in lower névé basins compensating for the diminution in higher ones.

The conditions which exist in the mountainous regions of the earth's actual surface are of course widely different from those of the hypothetical declivity. The maximum development of glaciers cannot in fact have occurred when the glacial isotherm touched the top of the highest mountain peak; for though the meteorological conditions were eminently favorable, insufficient space was afforded for the accumulation of névé. As the isotherm descended the slope of the mountains, the topographical condition became more favorable, while the meteorological tendency to the formation of glaciers decreased. The actual maximum development of glaciers on a given group of mountains therefore depended upon the maximum value of a function of two variables standing in an inverse ratio to one another. Of these, that which expresses the suitability of the topography to the accumulation of névé is incapable of general discussion and unquestionably varies not only with the group of mountains but with different portions of the same group. It is even conceivable that there should have been such fluctuations introduced by the character of the topography as to bring about alternate retardation and acceleration in the growth of glaciers or an equal development at widely removed periods of time, but these must be regarded as extreme cases, and in general there must be in the history of every group of mountains a period of maximum glaciation. It is by no means to be inferred, however, that this period was simultaneous in different groups of mountains, still less so at remote portions of the globe.

Various influences tend to prevent the formation of glaciers, such as the heat of the atmosphere, the heat of direct sunshine, the heat accompanying warm rains, and the velocity of air currents. The importance of these various influences differs greatly, and is scarcely what, on first thought, might be supposed. The mean temperature of the atmosphere may vary within very wide limits consistently with the existence of ice. It is a well known fact that in deep gorges, even in very temperate climates, snow and ice when protected from the direct rays of the sun often last far into the summer or even throughout the year, and in spite, too, of an active circulation of air. Glacial ice even accumulates in artificial openings in localities far removed from any mountain glacier. The bottom of the Dannemora iron mine, for example, an immense open pit some 500 feet deep, is covered with ice to a depth of many feet throughout the year, although the sun sometimes shines upon it for a small portion of the day. Here, however, though the circulation of the air must be considerable, and is accelerated by the hoisting, blasting and other operations, incident to the working of the mine, the cold air probably accumulates to a

greater extent than is possible in the deep gorges in the White Mountains, the Adirondacks and elsewhere, in which ice is nearly or quite permanent. Such occurrences make it clear that the direct heat of the sun is of the first importance in the dissipation of glacial ice or névé.

A certain amount of névé is not melted but evaporated. Indeed, according to Professor Whitney, the snow on the southern side of Mt. Shasta diminishes in volume almost exclusively from this cause, but a fixed amount of heat employed in dissipation by evaporation must produce a far smaller effect in the reduction of accumulated névé, than if it were employed in merely melting the snow or ice, for evaporation can go on rapidly only in dry air; and since the air is an extremely poor conductor, and has a low specific heat, most of the latent heat absorbed in volatilization of the water must be withdrawn from the underlying snow, and will thus counteract the tendency to melting. Indeed, since it is said to be possible to freeze water by evaporation and radiation from its own surface under favorable atmospheric conditions, at temperatures much above the freezing point, it is *à priori* probable that in a very dry atmosphere evaporation from a snow surface may be so rapid as to preclude melting, just as Professor Whitney has observed. Even when this is not the case, volatilization must retard melting. The melting effect of rain is no doubt very considerable, though as a certain quantity of water appears to be essential to névé, some rain is probably not unfavorable to the growth of glaciers. The melting effect of rain upon snow can readily be calculated if the temperatures of the two substances are known. If that of the rain is plus 5° and that of the snow minus 5°, the melting of a weight of snow equal to one sixteenth part of that of the rain, will reduce the latter to zero.

Still air can have very little effect upon the névé; the influence of winds is much greater, and is probably proportional to their velocity. Their effect, however, is almost wholly in one direction, for as long as any ice remains, warm currents of air will continue to dissipate it, and evaporation will proceed even below the freezing point. The chilling effect of cold winds, on the contrary, will reach but a short distance beneath the surface, for ice is a bad conductor, and however far below the freezing point the upper layer of the névé may be cooled, the underlying mass will be but very slightly affected. Of the influences tending to dissipate glaciers, none would seem to have been more vigorous at warmer stages of the earth's history, excepting the heat of the direct sunshine; and this, though more intense, was perhaps of shorter duration, for the mere fact of greater precipitation probably involved more cloudy weather or a shorter exposure of the ice to sunshine.

Hitherto it has been assumed that the warming of the sea, the evaporation and the precipitation, leading to the formation of a particular glacier take place under a sun heat of equal intensity, as would happen if there were no ocean currents and all these processes went on in the same latitude. Were this the case the lines of maximum glacier formation would first touch the earth as infinitesimal circles at the poles, and would thence move toward the equator remaining parallel to it. At any given period, maximum glaciation would be an event of the past throughout those portions of the globe lying north of the northern glacial isotherm and south of the southern one, while between them it would not have been reached. A different result must necessarily follow from the presence of open seas, for it is the most familiar fact in physical geography that heated waters from the tropics move poleward. Let it be supposed that at a given time in any given latitude distant from the equator there were no oceanic currents, and that the maximum of glaciation compatible with this condition of things had just been reached. If the barriers to the movements of the sea were then removed, water more highly heated than that characteristic of the latitude would flow in from the direction of the equator. An increase of evaporation and of precipitation would of course result, and the glacial isotherm would withdraw to a slightly higher altitude, but the sun's melting power would be unaffected and an immense increase would take place in the accumulation of névé. The action of aërial currents would be similar.

In the tropics, the conditions would be reversed. When the world is so cold that the glacial isotherm intersects the mountain slopes near the equator, the sun will not have its full effect upon the sea which constantly loses heated waters and receives cold currents. The glaciation at the equator will therefore be less than it would have been, had the surface waters been prevented by land barriers from seeking the poles. The glacial isotherm at the equator will be slightly lowered by the cooling of the ocean, but not in full proportion to the decrease of temperature at sea-level.

It follows that the rate of decrease of temperature with altitude will be more abrupt at a distance from the equator, during maximum glaciation, than it will be at that line when glacial formation there reaches its most rapid development, and since both evaporation at sea-level and the rate of decrease of temperature in the snow belt will be greatest in high latitudes, it is there that the extreme development of glaciers in the entire history of the earth, must take place. This highest development or absolute maximum of glaciation will occur where the influence of the warm oceanic currents is greatest, or where the

temperature of the surface waters is most raised above the temperature which they would possess were the water stationary. The present position of such a line could probably be ascertained, but in the past and warmer stages of the earth's history, more intense radiation from the sun probably stimulated these currents to much greater activity, and a somewhat different distribution of land probably modified their courses. It is quite sufficient for the purposes of this paper to point out that the absolute maximum lines of glaciation cannot have lain in the tropics, and can scarcely be supposed to have been further removed from them than the arctic circles; in short, it is most reasonable to suppose that the greatest development of glaciers would occur in somewhere from 40° to 70° of latitude. It is scarcely necessary to point out that this inference accords extremely well with the geological records of an ice age, though not with the hypothesis of a polar ice cap.

If the generally received view, that the sun is a gradually cooling body, is correct,* it appears therefore nearly certain that the absolute maximum in the development of glaciers is past, and that the glacial period was not one of general cold, but one of higher mean temperature at sea level than the present. This is not equivalent to a denial that other causes than those discussed have had an influence, and perhaps a great influence upon glaciation. Indeed, it seems more probable that the formation of glaciers was affected by all contemporaneous changes, such as extraordinary upheavals and subsidences or periodic fluctuations in the eccentricity of the earth's orbit; but if the reasoning offered is correct, it is not necessary to resort to such events to account for the occurrence of a glacial epoch while many years may elapse before it can be conclusively proved whether the causes adduced were quantitatively more or less than sufficient to account for all the facts inexplicable except as results of glacial action.

Office U. S. Geological Survey,
San Francisco, May, 1883.

* It appears to me, I confess, that substantiation of this hypothesis would be by no means superfluous.

ART. XXI.—*Analyses of two varieties of Lithiophilite (Manganese Triphilite)*; by S. L. PENFIELD.

THE author has already published* analyses of both triphylite and lithiophilite from the various known localities, and he regards it of interest to add to these two additional analyses, one of lithiophilite from Tubbs Farms, Norway, Me., a new American locality, the other of a variety from Branchville, Conn. The specimens from Norway, Me., are associated with quartz, albite and tourmaline, and are broken fragments of considerable size, blackened on the exterior by oxidation, to which the mineral is peculiarly liable, but in the interior perfectly fresh and of a light salmon color. Specific gravity, 3·398.

Two varieties of lithiophilite from Branchville have already been described from independent but closely contiguous deposits. The first of a light salmon-pink color, containing from three to four per cent of iron protoxide, the second of a light clove-brown color, containing thirteen per cent of iron protoxide. A third variety, from an independent deposit, is of a very pale bluish tint, of a brilliant luster, clear and transparent. Specific gravity, 3·504.

The analyses of these varieties gave the following results:

	Norway, Me.	Branchville, Conn.
P_2O_5	44·40	44·93
FeO	8·60	16·36
MnO	35·98	28·58
CaO	·78	·05
Li_2O	8·50	8·59
Na_2O	·14	·21
H_2O	1·19	·54
Gangue	·12	·13
	99·71	99·39

These analyses fully substantiate the formula of an orthophosphate, $Li(Mn, Fe)PO_4$, already made out for the species, giving the following ratios:

	P	Mn with Fe and Ca	Li with Na
Norway	1	1·02	0·91
Branchville	1	1·00	0·91

If part or all of the water be taken as basic the ratios are still closer.

These analyses, taken together with those of triphylite and lithiophilite already published, make an interesting series, showing the close relation and gradual transition between the two extremes of a lithia-iron phosphate containing very little manganese and a lithia-manganese phosphate containing but little iron.

My thanks are due to Professor George J. Brush for kindly providing me with material for carrying out these investigations.

Sheffield Scientific School, June 22, 1883.

* This Journal, III, xiii, 426; III, xvii, 226.

ART. XXII.—*On the Intensity of Sound.*—I. *The Energy and Coefficient of Damping of a Tuning Fork;* by CHAS. K. WEAD.

No one doubts that a sounding body is distributing energy, and that a sound-wave is one mode of transmitting energy; but in most practical cases the quantity of energy involved is so small as to elude easy measurement, and the problem is sometimes complicated by physiological questions. Attention has been directed mainly, in acoustical measurements, to finding the velocity of sound in various media, and to determining the vibration-frequency of the notes of the scale and of sounding bodies; this last problem has been solved experimentally in more than a score of ways, from the simple rod-tonometer that was so serviceable in the hands of Chladni and Scheibler, up to the refinements of Mayer's electrical method, and Rayleigh's, Macleod and Clarke's, Poske's and Michelson's methods, and König's fork-clock. But from time to time a number of contributions have been made to this subject of energy. Our text-books, however, so seldom refer to them that one is surprised on looking up the matter to see how much has been done; yet in so disconnected a way that considerable connecting matter is needed. It is hoped that this paper may supply a part of what is needed. In saying that our books give us little on the subject, of course it is meant few quantitative results; we find easily enough the law of inverse distances given, with the pretended proof, by striking four bells twice as far from the ear as a single similar bell is; the use of resonance cases and sounding-boards is familiar, of speaking and hearing trumpets, of the deadening effect of a non-homogeneous atmosphere, etc.; all these and similar things are pleasantly told, with more detail than in any other book I have met with, in Radau's Wonders of Sound.

In recent years the question of Energy has come up in new ways, as in finding the Potential at any point due to a vibrating body, and in deducing the equations of harmonic motion as is done by Lord Rayleigh, from assuming that the sum of the kinetic and potential energy in the vibrating body is constant; but here as before we have no numerical data given to help toward clear thinking.

We may consider our subject under three heads:

A. Instruments to which a store of energy is imparted at once, and which are then left to themselves; e. g. tuning fork, bell, and all stringed instruments.

B. Instruments that store up little or no energy, and so need a constant supply from outside: e. g. all wind and reed instruments, singing flames, and the voice.

C. Physiological questions; the loudness of sound, etc.; something of this must be anticipated under A and B. I have found very little in print bearing on A, more will be cited under B, while much has been done on the physiological side.

I. The Tuning Fork.

All bodies of class A are deformed at the outset by a blow or otherwise; the potential energy thus acquired may be measured with comparative ease in some cases as will be seen; let the calculation and measurement of this be the first problem.

In any elastic body, within the limits for which Hooke's law is true, the potential energy of the distorted body $=V=\frac{1}{2}Wa$, where $W=$ the force applied, and $a=$ the distance through which the point of application of the force moves. If $P=$ the force when $a=1$, then (1) $W=Pa$ and (2) $V=\frac{1}{2}Pa^2$. Since practically a fork is very nearly a representative of a bar fixed at one end and free at the other (3) $a=\frac{4Wl^3}{bd^3E}$, where $l=$ the length of the prong, $b=$ its breadth, $d=$ the thickness, and $E=$ Young's modulus; for steel $E=2{\cdot}14\times10^{12}$ in C. G. S. units (Everett), and for König's forks $b=1{\cdot}4$ cm. and $d=0{\cdot}65$ cm. approximately; therefore (4) $P=2{\cdot}056\times10^{11}\div l^3=$ the force in dynes, which applied at the end of the prong will bend it 1 cm.; and

$$(5)\quad V=\tfrac{1}{2}Pa^2=\frac{1{\cdot}03\times10^{11}a^2}{l^3}\ \text{Ergs.}$$

It would be more convenient to express V as a function of N, the vibration-frequency, than of l; this may be done by Mercadier's formula;* here as before $d=$ the thickness in cm., $l=$ the length of the prong, which I take as the length from the upper side of the stem plus half the thickness, and the constant is determined so as to satisfy best the observations; the average difference between the observed and computed values of N is a little less than 1 per cent. The Ut_3 and Sol_3 are thinner than the others and so relatively shorter, and were omitted in determining the constant; besides Ut_3 is not uniform in thickness.

$$(6)\quad N=82550d\div l^2.\quad \text{Therefore}$$

$$(7)\quad P=16540N^{\frac{3}{2}}.\qquad (8)\quad V=\tfrac{1}{2}\times16540N^{\frac{3}{2}}a^2.$$

For $Ut_2=128$ *d. v.*

$$(9)\quad V_2=\tfrac{1}{2}\times23{\cdot}94\times10^6a^2\ \text{Ergs.}$$

For any other fork of this series of harmonics of Ut_2, if h represents the number of the harmonic,

* Comptes Rendus, lxxix, 1001, 1069.

(10) $2Vh = 23{\cdot}94 \times 10^6 h^{\frac{5}{2}} a^2$ Ergs. = Potential Energy in *both* prongs

when the end of the prong is bent a centimeters.

If the fork is vibrating without giving over-tones, twice in each period its energy is wholly potential, and we may use equation (10) to compute it. The energy of the vibrating rod will actually be a very little greater than of the rod bent into the form of the elastic curve having the same maximum ordinate; for on comparing the curve of a bar fixed at one end given by Rayleigh (i, 231) with the elastic curve, we see that the latter lies everywhere, except at the ends, a very little nearer the line of equilibrium; but the difference in energy is too small to be considered here. The error is greater if the prong ought to be treated as the free end of a straight rod with two nodes, as a comparison of Rayleigh's Figs. 28 and 31 will show; but the latter assumption is certainly further from the truth than the former one.

I have used the method given above for finding the energy, rather than the one taken by Rayleigh (i, 202); because for experimental purposes it is more convenient to express the energy in terms of the amplitude rather than of the radius of curvature.

Experiments.—The forks named in table I were removed from their boxes, and supported firmly under a microscope carried by a dividing-engine with a millimeter screw, the plane of bending of course being parallel to the screw, and the prongs vertical; a cord passed from each prong over a pulley to a scale-pan in which the weights were put; the microscope was focussed on a point on the end of the prong, and then the distance measured between two points, one on each prong, as weights were added in the pans; this gives $2a'$ (a' is expressed in mm., while a was taken in cm.). But as the microscope had to be moved about 20 mm. to pass from one point to the other, a more rapid method was devised, that proved more accurate: a small block of wood was screwed into the end of the microscope-tube carrying at its lower end a brass plate bent thus: $\overbrace{\quad c \qquad b \quad}$; the distance bc was about 30 mm.; a wire ran from the plate through a telegraph sounder to a battery whose other pole was connected to the fork. A series of observations consisted in observing the difference of reading of the screw when electric contact was made at b and then at c, usually 1 or 2 mm.; equal weights were then put in the two pans, 1, 2, 3 and 4 kg., and the screw readings again observed; their difference is less than before by $2a'$; at least two determinations were made, and the friction of the pulleys eliminated by taking readings when

the pans were pulled down as far as they would remain, and when raised as high as they would remain. The value of the quotient $2a' \div W'$ is given in table I, col. 5; a' is here in mm. and W' in kg. The results under Mi_3 which are in [ ] were obtained by drawing the prongs together instead of separating them, as in all other cases; these are less reliable, because of the friction of the strings which had to cross each other. A small correction must be made to these results in col. 6; for the forces were not applied at the end, but usually $1\frac{1}{2}$—2 mm. below it, and the measurement was made above the point of application of the force, usually 1 mm. from the end. It seems hardly necessary to explain the details of the calculation, as it is easily made from the equations of the elastic curve, and of the angle between it and its tangent at the point where the force is applied. In only two cases does it amount to ·010 mm.; on the Ut_2 the forces were applied 16 mm. below the ends of the prongs.

TABLE I.

1	2	3	4	5	6	7	8	9	10	11	12	13
Fork	Length.	Method.	W'	$2a' \div W'$.				$P' = 2W' \div 2a'$	P Obs. C.G.S.	P From (7)	Dif. $\div$ P (10)	$2V =$ Energy Ergs.
				Obs.	Mean.	Cor.						
	Mm.		Kg.	Mm.			Mm.	Kg. Mm.	$10^7 \times$	$10^7 \times$		$z^2 \times$
Ut_2	203	Elec.	2	·772								
			3	·772	·772	·125	·897	2·22	2·18	2·39	—·10	450
Ut_3	141	Micr.	1	·325								
			2	·323								
			3	·327								
			4	·323								
			4	·324								
			2	·315								
			4	·316	·322	·005						
		Electr.	2	·320								
			4	·320	·320	·009	·328	6·10	5·98	6·77	—·13	1235
Mi_3	130	"	2	·217								
			4	·215	·216	·007	·223	8·97	8·80	9·47	—·06	1820
		["	2	·227								
			4	·235	·229	·011	·240	8·33]				
Sol_3	116	"	2	·174								
			4	·172	·173	·007	·180	11·11	10·9	12·46	—·14	2250
Ut_4	104	"	2	·103								
			4	·098	·101	·004	·105	19·0	18·7	19·16	—·02	3860
Sol_4	84									36·0		7500
Ut_5	72	"	2	·026								
			4	·034	·030	·002	·032	62·5	61·3	54·2	+·12	12670

All the observations were made at temperature of 15°—20° C. The other columns in table I give

9. $P' = W' \div a' = 2 \div (2a' \div W')$ where the accents indicate kg., mm. units.

10. P in C. G. S. units. $P=P'\times 981\times 10^4$.

11. P computed from equation (7).

12. The difference between 10 and 11 divided by P in col. 10.

13. The energy in both prongs of a vibrating fork when its amplitude is expressed in divisions of a micrometer; 220 div. $=1$ cm. The energy $=2\times\frac{1}{2}P\left(\frac{z}{220}\right)^2$, where P is to be taken from column 10, and z is the amplitude.

Loss of Energy from the fork.—The usual equation for the motion of a body in a resisting medium is

$$(12)\quad u=A'e^{-\frac{1}{2}\kappa t}\sin\{\sqrt{p_2-\tfrac{1}{4}\kappa^2}t-\alpha\},$$

where κ is the coefficient of damping, and t is the time measured from the instant when $u=0$ (Rayleigh i, 37); $A'e^{-\frac{1}{2}\kappa t}$ will correspond to a' in our equations. The energy at any instant is equal to $P'a'^2=P'(A'e^{-\frac{1}{2}\kappa t})^2$, being sensibly constant throughout any one period. Therefore

$$(13)\quad \text{Kinetic energy}=2T=2P'A'^2e^{-\kappa t}=2P''A^2e^{-\kappa t}=P''z^2=2V,$$

where P″ is the number in table I, column 10, divided by $(220)^2$, and A is the amplitude (in micrometer divisions) when $t=0$; 2V is given in column 13; z is the amplitude in micrometer divisions at the time t.

The rate of loss of energy $=$

$$(14)\quad \frac{2d\mathrm{T}}{dt}=-2\kappa P''A^2e^{-\kappa t}=-2\kappa T=2\kappa V.$$

We must then determine κ from the equation $z=Ae^{-\frac{1}{2}\kappa t}$, whence $\kappa=2$ Nap. log. $\frac{A}{z}\div t$; it is more convenient in this case to take the second as the unit of time, rather than the period of vibration as is sometimes done in experiments on damping. For the experiments an upright post about two inches square fixed to a solid base was taken, and to it the resonance case, on which the fork was firmly screwed, was clamped by a carpenter's clamp. Above, a bar held by another clamp supported the brass arm carrying the microscope tube in a vertical position; a little black antimony powder * was gummed on the tip of the fork and these minute particles furnished fine bright points under the microscope, having often a breadth less than $\frac{1}{200}$ mm. The magnifying power used was about 45, and the divisions of the eye-piece micrometer (a glass scale ruled to $\frac{1}{5}$ mm.) were, as already stated, almost exactly equivalent to $\frac{1}{22}$ mm. The adjustments of the apparatus were easy and direct, and the stability almost perfect. To measure the time a stop

* Suggested by Terquem, Phil. Mag., March, 1874; C. R. lxxviii, 125, 1874.

watch was used (an "Auburndale timer"), held in the left hand, while the right hand was free to use the bow and make records; the pointers gave directly $\frac{1}{8}$ second. Thus the time was found which was necessary for the amplitude to decrease from z' to z''. An example will indicate in a general way the accuracy of the method. Fork Ut_3; $z'=12$ div., $z''=6$ div.; time $=9\frac{5}{8}$, $9\frac{7}{8}$, 10, 11, $10\frac{1}{8}$, $9\frac{7}{8}$, $9\frac{5}{8}$, $10\frac{1}{8}$, 10, $9\frac{7}{8}$, $10\frac{3}{8}$, $10\frac{3}{8}$; mean 10·08 sec. These were not consecutive observations, and several points were taken. When z is large the point must be comparatively broad to be seen; while if z is small the finite breadth of the "point" and of the lines on the scale leads to uncertainty.

Table II gives for one of the forks used the mean value of $\varkappa$ for a number of intervals. It is an unexpected fact that $\varkappa$ varies so much with the amplitude; only Poske,* so far as I have discovered, refers to it, and then incidentally. It is a proof that the resistance to the motion of a fork is not expressed by a term proportional to the first power of velocity simply, but the second and perhaps higher powers must come in; the equation of motion would be $\ddot{u}+\varkappa\dot{u}+\lambda\dot{u}^2+n^2u=0$. But this is not integrable, and even the results which Poisson gives for the case when $\varkappa=0$ shed no light on this case; we must therefore determine $\varkappa$ empirically as a function of z and introduce the corresponding value of $\varkappa$ into equation (14).

TABLE II.

1	2	3	4	5	6	7	8	9
Fork.	No. obs.	z'	z''	$\frac{z'+z''}{2}$	t	κ obs.	κ comp.	Dif.
Sol_3	5	10	5	7·5	4·70	·295	·295	+·000
	4	9	3	6	9·05	·243	·253	− 10
	2	9	2	5·5	14·30	·210	·239	− 29
	2	8	5	6·5	3·19	·293	·267	+ 26
	11	8	4	6	5·34	·259	·253	+ 6
	4	8	3	5·5	8·19	·239	·239	0
	4	8	2	5	12·81	·216	·225	− 9
	4	6	3	4·5	6·31	·220	·211	+ 9
	2	6	2	4	11·0	·200	·197	+ 3
	6	5	3	4	5·14	·199	·197	+ 2
	5	5	2	3·5	10·05	·182	·183	− 1
	3	4	2	3	8·17	·170	·169	+ 1
	3	4	1	2·5	17·75	·156	1·55	+ 1
	55						13)	+ 48
								− 49
								±·008

It will be seen that the observations are fairly represented by putting

* Pogg. Ann., clii, 470.

$$(15)\quad \varkappa = a + b\frac{z' + z''}{2};$$

$\frac{1}{2}(z'+z'')$ is the average of the amplitudes at the beginning and end of the time t; $\varkappa$ cannot be expressed as a simple function of the time; so the equation corresponding to (12) can only be solved by successive approximation. Equation (15) leads to the expression $\varkappa = a + bz$, for the coefficient of damping corresponding to the amplitude z; therefore instead of (12) we have when t is small, putting z' for A,

$$(16)\quad u = z' e^{-\frac{1}{2}(a+bz')t} \sin\left\{\sqrt{p^2 - \tfrac{1}{4}(a+bz')^2}\, t\right\}:$$

if we wish to make t more than a few periods replace z' in the exponent by $\frac{1}{2}(z'+z'')$, where z'' is the amplitude at the time t. Obviously

$$(17)\quad z'' = z' e^{-\frac{1}{2}\{a + \frac{1}{2}b(z'+z'')\}t}.$$

As I do not find any discussion of such an equation as (16) it is well to show what is involved in it. Differentiating twice and dropping the accent from z' we get

$$(18)\quad \ddot{u} + a\dot{u} + bz\dot{u} + p^2 u = 0.$$

Represent the mean value of $\dot{u}$ during a quarter period by $(\dot{u})$; of $\dot{u}^2$ by $(\dot{u}^2)$; and the mean value of $(\dot{u})\dot{u}$, that is, the mean value of the product of the velocity at any time and the mean velocity, by $((\dot{u})\dot{u})$; and neglect the second term under the radical in (16), since in no case for the forks of the present series does it equal $p^2 \times 10^{-7}$. These familiar methods give *

$$(19)\quad (\dot{u}) = \pm\frac{2p}{\pi} z. \qquad (20)\quad ((\dot{u})\dot{u}) = \pm\frac{8}{\pi^2}(\dot{u}^2) = \pm\frac{8}{\pi^2} \times p^2 \frac{z^2}{2}.$$

Whence

$$(21)\quad \ddot{u} + a\dot{u} \pm \frac{\pi b}{2p}(\dot{u})\dot{u} + p^2 u = 0.$$

The mean value of the third term =

$$(22)\quad \pm\frac{4b}{\pi p}(\dot{u}^2) = \pm\frac{2b}{\pi p} z^2;$$

the upper sign is to be taken when $\dot{u}$ is +, i. e. when the angle pt is in the first or fourth quadrants, otherwise the lower sign. In the same way then as we may say that $(\dot{u})$, the mean value of $\dot{u}$ and $(\ddot{u})$, vary as z; so the mean value of the third term varies as z^2, and therefore both as $(\dot{u})^2$, the square of the mean velocity, and as $(\dot{u}^2)$ the mean square of the velocity; not, however, as the square of the variable velocity. If $b=0$ of course we get the usual equation of harmonic motion in a resisting medium.

* In strictness equations (19) and (20) are true only when $a=b=0$; but the error here is very small.

Turn now to the results of the experiments.

Table II is a specimen of the table made out for each of the forks used; it gives the mean time required for the amplitude to decrease from z' to z'', the number of observations from which this mean is deduced, the resulting value of $\varkappa$, $\varkappa$ computed from the equation $\varkappa = \cdot085 + \cdot028\frac{z'+z''}{2}$, and the differences between the observed and computed values. Where these errors are large it will be seen that few observations were taken or z'' was small.

Table III gives an abstract of table II and similar abstracts for the other forks; it gives the number of ratios observed, the number of observations, the maximum value of z' and the minimum value of z'' used in deducing $\varkappa$; the longest time observed, the coefficients a and b, and the average difference without regard to sign between the observed and computed values of $\varkappa$ as found from such data as table II, col. 9. I think we may conclude that equations (16) and (17) satisfy the observations; if any term in the exponent is to be sought depending on $\frac{1}{3}\frac{z'^3-z''^3}{z'+z''}$, very much more refined methods than these must be devised.

TABLE III.

1	2	3	4	5	6	7	8	9
Fork.	No. ratios.	No. obs.	Max. z'	Min. z''	Max. t.	a	b	Av. dif.
Ut_2	4	23	20	3	7·30	·180	·003	±·006
Ut_3	9	38	15	2	20·5	·065	·008	±·002
Sol_3	13	55	10	1	17·75	·085	·028	±·007
Ut_4	9	37	6	1	17·72	·122	·022	±·002
Sol_4	8	32	5	1	5·87	·460	·028	±·012
"	4	54	5	1	6·87	·237	·044	±·006
Ut_5	3	17	4	1	3·33	·112	·100	±·007
"	2	21	4	1	4·48	·400	·050	
"	4	23	5	1	7·5	·225	·062	±·008

But while a good degree of confidence may be placed in the results, it should be observed that any considerable change in the mode of supporting the fork will change $\varkappa$ for any given amplitude. Thus:

Ut_2 in Table III is properly mounted before its case (not on it), $\kappa = \cdot180 + \cdot003\ z$.
Ut_2 screwed to a board, without case, gave ..... $\kappa' = \cdot048 + \cdot0036\ z$.
Ut_3 on its box, box clamped on its side ..... $\kappa = \cdot065 + \cdot008\ z$.
Ut_3 on its box, box standing on table and iron block in box ... $\kappa = \cdot075 + \cdot004\ z$.
Ut_3 on its box, box standing on table and iron block in box, ... time from 5 to 3 $= 9\cdot12$ sec.
Ut_3 on its box standing on table ..... time from 5 to 3 $= 7\cdot7$ sec.
Ut_3 on Sol_3 box ..... time from 5 to 3 $= 9\cdot0$ sec.
Sol_3 on box, clamped at side ..... $\varkappa = \cdot085 + \cdot028\ z$.
Sol_3 on box, standing with weight on box, ... $\varkappa = \cdot113 + \cdot028\ z$.

Even when the conditions were similar, so far as known, considerable differences were found in x for the same values of z', z'', as table III shows for two forks; the last line has been used in the succeeding computations when the table shows more than one set of observations. I suspect that a part of the variability of b may be due to a different strength of the overtones at different times.

The numbers in column 8, table III (taking the last line for Sol_4 and Ut_5), show such a regular increase as to render it at least plausible that the term containing b depends on the resistance of the air to the faces of the prongs. Schellbach* has shown that the resistance of the air to discs varies as v^2, even when v is as low as 17·1 cm. per sec. In these forks the mean velocity will be $\frac{2}{\pi} \times \frac{2\pi zn}{220} = \cdot 01818zn$ cm. per sec., where z is given in micrometer divisions, and n is the vibration-frequency. If the forks have the amplitudes given in table IV, column 7, the least value of $\cdot 01818zn$ is 18·6 cm. per sec., while for most of the forks the value is about 37; the velocities for an ordinary vibration are therefore higher than in Schellbach's experiments, and so we may assume that the air-resistance varies as v^2. We may also assume that the resistance varies directly as the length of the fork when other conditions remain the same:

$\therefore R = (\cdot 01818)^2 z^2 n^2 l^{-1} \times$ a constant; by Mercadier's formula (6) $nl^2 =$ a constant.

(22) $\therefore R = kz^2 n^{\frac{3}{2}}$, where k is a constant depending on the breadth, thickness and modulus of elasticity of the prongs, the form of the curve which the vibrating prong assumes, the density and viscosity of the air, and perhaps on other things; but for the forks of this series it is considered constant. Accordingly b in table III, col. 8, should vary as $n^{\frac{3}{2}}$.

Taking $Ut_2 = 1$ we get the two series:

$n^{\frac{3}{2}} =$	1·	2·83	5·2	8·	14·7	22·6
$b =$	·003	·008	·028	·022	·044	·062
$1000b \div n^{\frac{3}{2}} =$	3·	2·8	5·4	2·7	3·	2·7

Considering the difficulty of determining b with accuracy, the close agreement of the quotients in the last line seems remarkable. No change has been made in table III since these calculations were made; so there has been no possibility of biasing the judgment in favor of this regular increase of b.

The energy that the fork loses is expended in these ways:

1. In heating the fork, and the wood of the resonance case; 2. In communicating tremors to the support; 3. In producing

* Pogg. Ann., cxliii, 10.

a sound wave. It is doubtful if the first and second can ever be separated from the total; however large a fraction of the total 1 may be, it is very small absolutely; all the energy that can be given to a fork by a bow would not suffice to heat the fork $\frac{1}{1000}$° C. in the most favorable case in table IV (Ut_5, col. 6). Table IV is drawn up to show roughly the amount at our disposal in these forks. Col. 2 is the same as col. 13, table I; 3 gives approximately the maximum value of z that can be given by a bow; 4, the corresponding energy; 5, the corresponding value of $\varkappa$ obtained by extrapolation, since accurate observations could not be made with such values of z; 6, the maximum rate at which energy is given up. Cols. 7–10 give similar data for an ordinary or average value of z. Mayer* finds from the heating of a bit of rubber between the prongs of Ut_3 fork vibrating electromagnetically, that 54 foot-grains of work are given up to the rubber in 10 seconds; this is equal to 10500 ergs. per sec.; the data in table IV would give this value of $2V\varkappa$ when z is a little less than 9 div., or about 0·4 mm.—a very satisfactory agreement.

TABLE IV.

1	2	3	4	5	6	7	8	9	10
Fork.	2V	Max. z	Max. 2V	κ	$2V\kappa$	Av. z	Av. 2V	κ	Av. $2V\kappa$
	$z^2 \times$		Ergs. $10^3 \times$		Ergs, sec. $10^3 \times$		$10^2 \times$		Ergs.
Ut_2	450	30	405	·27	110	8	290	·20	5800
Ut_3	1235	20	490	·225	110	6	445	·11	4900
Sol_3	2250	13	380	·45	170	5	560	·225	12600
Ut_4	3860	9	310	·32	100	4	620	·22	13600
Sol_4	7500	7	370	·49	180	3	675	·35	24000
Ut_5	12700	6	456	·61	280	2	510	·35	18000

The ultimate object for which these experiments were begun was to determine how much energy was needed to cause sensation, or rather how much energy passed through 1 square cm. at the limit of hearing; for it was believed that the "efficiency" of the tuning fork would be higher than of other sources of a sound-wave.

The forks were taken out of doors to a field where the listeners might be 300 feet distant from the fork. This was sounded on the frame described above, and the amplitude observed when the different listeners shouted "out." The separate observations were quite consistent, considering that passing teams and a rising wind increased very much the difficulty of observation. Sometimes the observers changed places, or the fork was directed toward different parts of the field. The observation

* This Journal, viii, 362.

on Sol_4 was the last and was interrupted by a shower, so that less confidence is to be placed in it than in the others; but all will give results greatly above those to be obtained under more favorable conditions; inconsistent as these results are, they are all of the same order of magnitude, and may deserve publication because, so far as I can find, no similar work has been published.

Table V gives the results of these field observations; the number of observations for each listener is given, and the mean of the values of z observed when he shouted "out." Nearly all through the scale the observer Y, who is a musician, showed a higher sensibility than the others, whether the wind was toward him or from him.

TABLE V.

1	2	3	4	5	6	7	8	9	10
Fork.	Obs.	50 ft.		100 ft.		200 ft.		300 ft.	
		No. obs.	z	No. obs.	z	No. obs.	z	No. obs.	z
Ut_2	Y	5	3·4	8	6·8				
	T	5	3·9	5	7·0				
	E	5	3·5	4	7·0				
	G	5	4·	5	7·0				
			3·7		7·0				
Ut_3	Y			1	1·	4	2·4	4	3·9
	T			1	1·5	4	2·5		
	E			1	1·5	4	2·4	4	3·7
					2·5		2·5		3·8
Sol_3	Y					6	1·2		
	T					6	1·8		
	E					6	1·5		
							1·5		
Ut_4	Y					12	2·0		
	T					8	2·1		
							2·0		
Sol_4	Y					6	1·5		
	T					6	1·5		
							1·5		
Ut_5	Y					7	·70		
	T					3	.75		
							·72		

In table VI are given the mean values of z of all the listeners together, and the corresponding values of 2V, x and $2Vx$ as in table IV. The energy expended per second, whose amount is given in col. 5, passes out through a hemispherical shell whose radius is given in col. 7; this statement assumes that the ground reflects all the energy that reaches it, which is the assumption tacitly made by Rayleigh* in his oft-quoted experiment.

* Proc. R. S., xxvi, 248.

(23) $\frac{2V\varkappa}{2\pi D^2}$=S= energy per sec. passing through the unit of surface at the limit of hearing; or for 200 ft.

$$S=\frac{2V\varkappa}{2\pi(200\times 30{\cdot}5)^2}=2V\varkappa\times 4{\cdot}3\times 10^{-9} \text{ ergs. per sec. per square cm.}$$

The values for S are given in col. 6. They seem to indicate that the ear is most sensitive to notes in the middle octave; but with regard to Ut_2 the listeners found it so near the pitch of the ever-present noises that it was more easily lost than other notes.

TABLE VI.

1	2	3	4	5	6	7
Fork.	z	$2V$	$\varkappa$	$2V\varkappa$	$S=\frac{2V\varkappa}{2\pi D_2}$	Distance.
		$10^2\times$		Ergs.per s.	$10^{-8}\times$	
Ut_2	3·7	62	·195	1200	8300	50 ft.
	7·0	220	·20	4400	7600	100 "
Ut_3	2·5	77	·085	650	280	200 "
	3·8	178	·09	1605	310	300 "
Sol_3	1·5	51	·12	610	260	200 "
Ut_4	2·0	150	·17	255	110	200 "
Sol_4	1·5	170	·30	5100	2200	200 "
Ut_5	·72	63	·26	1640	710	200 "

The Ut_2 fork was mounted *before* a resonance box, and fitted to be driven by an electro magnet; Ut_3, Sol_3 and Ut_4 were mounted on boxes of the usual form open at one end; the Sol_4 and Ut_5 were open at both ends. The Ut_2 was heard much better in front of the box than behind, but as there were four observers, and those before and behind the box exchanged places, any error from this difference is eliminated; no difference was detected with the other forks.

Two in-door experiments may be given: the Ut_2 was taken near one end of a long hallway, and, being turned in various directions, the amplitude was noted when the sound ceased to a listener about 50 ft. away; here we cannot apply the law of inverse squares; the best thing is to assume that all the energy passes through every transverse section of the hall, although we know that some was absorbed by the end wall, and some escaped by a stairway:

$$2V\varkappa=190 \text{ and area } =19\,\bar{m}^2 \therefore S<100000\times 10^{-8}.$$

Again the Ut_3 fork was heard about 2 m. distant when the amplitude was less than $\frac{1}{12}$; as the fork was near a wall, assume that the energy passed out through a quarter of a sphere; and

as the ear was at a point of maximum loudness, assume that the energy per second at that point is four times that due to a uniform distribution of the energy:

$$2V\pi < 0{\cdot}52\,;\ S < 4\frac{0{\cdot}52}{\pi \times (200)^2}\,;\ S < 1700 \times 10^{-8}\,;$$

table VI gives $S = 300 \times 10^{-8}$.

Some experiments were made bearing on the question of the division of the energy as already referred to; they indicate that with the Ut_3 fork only about $\frac{1}{15}$ of the total energy is used for the sound-wave; but the observations are too few to determine whether the theory used in their discussion is valid or not; so this matter must be deferred till another time.

The only other experiments that I know of with which to compare the values of S in table VI are three in number, from which I have computed the values of S as follows:

Töpler and Boltzman,* closed organ pipe, $n=182$ ..... $S = 10000 \times 10^{-8}$
Rayleigh,† open pipe, $n=2730$ ..... $S = 4500 \times 10^{-8}$
Allard,‡ bells, steam syren, etc., at sea, n from 400 to 1500 ..... $S = n \times 4{\cdot}3 \times 10^{-8}$

Following Rayleigh's formula we get the maximum velocity of the air particles at the limit of hearing, thus: $v^2 = S \div \frac{1}{2}a\rho$, where a = the velocity of sound $= 34000$ cm. and $\rho = {\cdot}0013$ = density of air; $\therefore\ v^2 = S \div 22{\cdot}1$; the amplitude of the vibration of the air particle $= x = v \div 2\pi n = \sqrt{S} \div 30n$. The smallest value of x to be obtained from table VI is 70×10^{-8} cm. for Ut_4. The formula computed from Allard's data would give for $n=512$, $x = 31 \times 10^{-8}$ cm. Rayleigh found for $n=2730$, $x = 8{\cdot}1 \times 10^{-8}$ cm.

But the fuller discussion of these matters must be postponed to another part of this paper.

* Pogg. Ann., cxli, 321, 1870.
† Proc. Roy. Soc., xxvi, 248, 1877.
‡ Comptes Rendus, xcv, 1062, 1862. I have not seen his longer memoir.

Art. XXIII.—*The Decay of Rocks Geologically Considered;* by T. Sterry Hunt, LL.D., F.R.S.

[Read before the National Academy of Sciences at Washington, April 17, 1883.]

Contents of Sections.—1, 2. The supposed relation of rock-decay to climate; 3, Decomposition of silicated rocks; 4. 5, Studies of Pallas, Fournet, J. F. Dana, Webster, Blake; 6, Of Hartt in Brazil; 7, Of Shepard in Connecticut; 8, 9, Whitney, Pumpelly and Dawson on decay of limestones; 10, A sub-aërial process; 11, 12, Its antiquity and its relation to glacial erosion; 13, Decay in the Blue Ridge; Hunt, Burbank; 14, 15, Chemical significance of decay of aluminous silicates; 16, Analyses of decomposed feldspars; 17, 18, The question in relation to eozoic rocks; 19, Bowlders in crystalline schists; 20, 21, Decayed gneiss of Hoosac Mountain; 22, Of the South Mountain, Penn.; 23, At Atlanta, Ga.; density of decayed rocks; 24–26, Cupriferous pyrites; its decay; iron and copper ores; 27–30, Limonites of the Appalachian valley; tertiary limonites (foot-note); 31–34, Lesley, Jackson, Frazer and Lyman on limonites; 35, 36, W. B. Rogers on formation and segregation of siderite; 37, 38, Limonites from serpentine of Staten Island; 39, Pumpelly on decay of petrosilex-porphyry in Missouri; its pre-Cambrian antiquity; 40, Of gneisses in Wisconsin and Minnesota; White, Winchell and Irving; 41. Rock-decay in Sweden and in Scotland; 42, Post-Cambrian decay of igneous rocks; 44, 45, Decay of auriferous gravels in California; influence of carbonic acid; 46, Slight decay in post-glacial times; effects of changes of temperature (foot-note); 47–49. Pumpelly on the geological relations of rock-decay; 50–52, Studies of Reusch in Corsica: 53, Conclusions.

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§ 1. The subject of the decay of rocks has not yet received from geologists all the attention which it merits, and there still appear to be misconceptions with regard to it which warrant us in reviewing some points in its history. Professor F. H. Storer,[1] in a recent notice of a suggestion of Nordenskiöld's as to the liberation of gems through the decay of the feldspathic rocks in which they are often contained, cites with approval the opinion of Professor Stubbs of Alabama that "the decomposition of these rocks in southern latitudes has proceeded much faster than with the same rocks in higher latitudes," a "condition which can be accounted for, to a large extent, by climatic influences." The cold and frost now prevailing in northern regions are supposed by him to retard the action of atmospheric waters, regarded as the chemical agent of this process of decay.[2] These views, implying that the process is one belonging to the present time, are accepted by Professor Storer, who writes of the "more active and thorough-going disintegration which occurs" in these southern regions.

§ 2. That the presence in the northern hemisphere of a mantle of softened material from the decay *in situ* of crystalline rocks is more common at the outcrops of these in low than in high latitudes, where it is often entirely absent, is a familiar fact; but it will, I think, be made evident that present climatic

[1] Science, for February 16, 1883, p. 29.
[2] Bernay's Hand-book of Alabama, 1878, p. 199.

differences have nothing to do with the fact that similar rocks are in one area covered with a thick layer of the products of decay, and in another are wholly destitute of it.

§ 3. The decay in question is well known to be due to a chemical change of which the predominant mineral silicates of the rock, chiefly feldspars and hornblende, are the subjects, and which results in the removal by solution of the protoxyd-bases, together with a great proportion of the combined silica, leaving essentially a residue of clay, mingled with quartz, garnet, magnetite and such other mineral species as resist the process of decomposition.

§ 4. A memoir, by Fournet, published in 1834,[3] gives many facts regarding the early observations on rock-decay. Its author there describes the wide-spread decomposition of the granites near Pont-Gibaud in Auvergne, a change which Deribier de Cheissac had already shown to be anterior to the deposition of the Tertiary rocks. Fournet, moreover, noticed the similar decay of basalts, phonolites, trachytes, and even obsidians, and described the process of exfoliation by which were left rounded masses of undecayed rock. He cites in this connection the observations of Pallas, who, in his travels in Siberia (1768-1774), noticed hills "that seemed composed of masses heaped together, as it were rounded by decomposition." The view of Werner that the rounded form of masses such as these was due to original concentric structure, was rejected by Fournet.

§ 5. In 1818, Messrs. J. F. and S. L. Dana described a similar phenomenon in the decaying greenstones at Somerville, near Boston, Mass., where the rock was found to be converted by decay *in situ* into nodular masses presenting exfoliating concentric layers of differing degrees of decomposition. These masses rest upon each other, decayed matter filling the interstices.[4] In 1825, T. W. Webster noticed the same example, and explained the formation of bowlders by the exfoliation of the decayed greenstone.[5] Again, in 1858, W. P. Blake described the production of rounded masses both of sandstone and of granite through disintegration. He explains how angular blocks, separated by joints admitting water to all sides, would be "attacked most rapidly on the angles, thus producing a succession of curved faces gradually approaching a sphere," and illustrates the process by figures. He described, moreover, the bowlder-like masses of granite in Placer County, California, lying on an uneven surface of the same rock, "as due to the manner in which the rock decomposes, and not to

[3] Ann. de Ch. et de Phys. [2] v, 225–256.
[4] Mem. Amer. Acad. Sciences, 1st Series, iv, 201.
[5] Boston Journ. Philos. and Arts, ii, 285.

abrasion." Like Fournet, he rejects the notion of an original concentric structure in the rock.[6]

§ 6. Hartt, in 1870, discussed the well-known examples of rock-decay found in Brazil, and called such rounded masses of rock as we have just described "bowlders of decomposition." He moreover noted that the process of decay was there anterior to the supposed glacial action, which had worked over the material of the previously decomposed rocks.[7] Lyell already, in 1849, had pointed out that the Tertiary clays and sands of the southern United States have been derived from the waste of the previously decayed crystalline rocks of the region;[8] and as we have seen, the ante-Tertiary age of the decay in Auvergne had long before been recognized.

§ 7. The account given by Professor Charles Upham Shepard, in 1837, of the origin and mode of occurrence of the porcelain-clays of western Connecticut is remarkable for its exactness and perspicuity. That at New Milford is described as occurring "upon the western slope of an elevated range of granitic gneiss. . . . . In many places the decomposition of the parent rock is so complete as to present the aspect of a secondary deposit; but the prevailing appearance is that of the rock altered in place through the decay of the feldspar and mica. Indeed, the same relative arrangement of the quartz and the altered feldspar is observed in the bed as is presented by these materials in the undecomposed rock. Veins and seams of a perfectly impalpable white clay traverse the rock in various directions, analogous to the veins of feldspar in the granite of the neighborhood." Of a pure white clay in the town of Kent, our author says, "It forms a vein many feet in width, cutting through quartz rock. It owes its origin to a graphic granite, which must have been free from mica." A similar vein of clay is described as occurring in the town of Cornwall, and as including frequent crystals of black tourmaline; the feldspar also being incompletely decomposed.[9]

§ 8. As showing that the process of sub-aerial decay is not confined to silicated rocks, it may be noted that J. D. Whitney described in 1862, the existence in the lead-region of Wisconsin of a layer of red clay and sand, mixed with chert, sometimes thirty feet in thickness, which he showed to be a residuum from the secular decay of several hundred feet of the impure Paleozoic limestones of the region.[10] A like occurrence was afterwards, in 1873, described by Pumpelly, in southern Missouri, where such residuary deposits sometimes attain a thick-

[6] Geol. Recon. of California, pp. 146, 286.
[7] Scientific Results of a Journey in Brazil, pp. 28, 573.
[8] Lyell: A Second Visit to the United States, ii, 28.
[9] Shepard: Report of Geological Survey of Connecticut (1837), pp. 73–75.
[10] Geology of Wisconsin, i, 121.

ness of 120 feet.[11] This process is evidently due to a simple solution of the carbonates of lime and magnesia in meteoric waters.

§ 9. A similar decay is conspicuous along the outcrop of the Auroral limestones and their associated schists in the Appalachian valley, as will be noticed farther on, in § 27, and may also be seen at several points in the Trenton limestone and the Utica shale of the St. Lawrence valley. One of these localities, described by Dr. J. W. Dawson, is at Les Eboulemens, on the north shore of the St. Lawrence, below Quebec. Here, at the southwest base of the high Laurentide hills, the Post-pliocene clays, enclosing marine shells and large gneiss bowlders, are found resting upon a mass of Utica slate, deprived of its calcareous matter, and so soft as to be readily mistaken for the newer clays of the region but for its stratification and its organic remains. This, according to Dawson, had been changed to a great depth by sub-aërial action previous to the period of submergence, during which it was covered with the bowlder-clay.[12] Some facts connected with the decay of the Trenton limestone near Montreal will be mentioned in § 42.

§ 10. It may be said that with the exception of Darwin, who had observed the decay of rocks in Brazil and conjectured that the process might have been sub-marine, all observers have correctly regarded it as sub-aërial. The chemistry of the process was discussed, among others, by Fournet in the paper already cited, and later by Delesse in 1853;[13] also very fully by Ebelmen, who considered the question of rock-decay in its relations to the atmosphere, in two memoirs in 1845 and 1847.[14] The same subject was further considered at some length by the present writer in 1880.[15]

§ 11. Having thus briefly indicated some of the points in its history during the past century, we are prepared to notice in more detail the contributions made to the subject, considered in its geological bearings, during the last ten years. Previous to this, as we have seen, it had been recognized that the process of rock-decay had been in operation not only in pre-glacial but in pre-Tertiary times, and that the resulting material had been the source of Tertiary clays and sands, and even, in certain cases, of glacial drift and bowlders.

§ 12. In a review of Hartt's volume on Brazil, in 1870, the present writer said: "The great wasting and wearing-away of crystalline rocks in former geological periods, of which we have

[11] Geological Survey of Missouri; Iron Ores and Coal Fields, p. 8.

[12] Dawson: Notes on the Post-pliocene Geology of Canada; from Canadian Naturalist, vol. vi, 1872.

[13] Bull. Soc. Geol. de France, x, 256.

[14] Annales des Mines [4], vii, and xiii.

[15] This Journal, xix, 349; see also his Chem. and Geol. Essays, p. 100.

abundant evidence, is less difficult to understand, when we learn that rocks as hard as those of our New York Highlands become [are] even in our own time, under certain conditions so softened as to offer little more resistance to the eroding action of a torrent than an ordinary gravel-bed.[16] Subsequently, in an account of some observations made in North Carolina among the rocks of the Blue Ridge, and presented to the Boston Society of Natural History, October 15, 1873, he expressed the belief that the decay of crystalline rocks was a process of great antiquity; that it had been universal; that the covering of decayed material now seen in the south at one time extended to the rocks of northern regions, from which it had been removed by erosion during successive ages, culminating in the Glacial period at the close of the Pliocene, since which time the chemical decomposition of the surface has been insignificant. From the products of this sub-aërial decay it was then maintained has been derived a great part of the sediments alike of Paleozoic, Mesozoic and Cenozoic times. The permeable nature of the surface-soil formed of highly inclined strata of decayed rocks, affording a natural subterranean drainage, explains, it was said, both the absence of lakes and the comparative permanency of the surface to be remarked in uneroded regions; showing that something more than ordinary aqueous agencies must have effected the removal of the decayed material.[17]

§ 13. This communication of mine was speedily followed by a paper published in the Proceedings of the Boston Society of Natural History for November 19, 1873, by the late Mr. L. S. Burbank, repeating and insisting upon the same conclusions, and, moreover, dwelling especially upon the process of decay (which he also had studied in North Carolina), as a preliminary to the formation of bowlders and glacial drift.

In accordance with the views thus expressed in 1870 and 1873, it was conceived that the power of the usual eroding agents, ice and water, would be inadequate to the removal of great areas of rock unless this had been previously softened by decay, and in a review of the subject by the present writer, in 1873, the conclusion was reached that the decomposition of rocks has been "*a necessary preliminary to glacial and erosive action, which removed already softened materials.*"[18] Such erosion and denudation would, in accordance with this view, consist in the removal of previously decayed rocks, and the forms and outlines of the sculptured surface thereby exposed would be determined by the varying depths to which the process of sub-

[16] The Nation, New York, Dec. 1, 1870.

[17] Proc. Boston Soc. Nat. History, Oct. 15, 1873, and this Journal, vii, 60; also Proc. Amer. Assoc. Adv. Science for 1874, p. 39; and Hunt, Chem. and Geol. Essays, pp. 10, 250.

[18] Harper's Annual Record of Science, etc., for 1873, p. xlviii.

aërial decomposition had already penetrated the once firm and solid rock. The basin-like depressions and the hillocks of the eroded surface, not less than the detached rounded masses or bowlders, were thus, as the writer has ever since taught, the results of the previous process of rock-decay.

§ 14. I had long before this time been led to insist upon the evidences of a wide-spread decomposition of crystalline rocks in very early periods of geological history. In an essay, entitled Some Points in Chemical Geology, published in 1859,[19] and another, on The Chemistry of Metamorphic rocks, in 1863,[20] both reprinted in my volume of Chemical and Geological Essays, I have pointed out the important part played by the protoxyd-bases liberated by the sub-aërial decay of feldspathic and hornblendic rocks. Starting from the conception of a primitive terrestrial crust consisting wholly of crystalline silicated rocks, we are forced to find in such a process of decay the source of all limestones and dolomites, which are derived from the carbonates of lime and magnesia generated either directly, during the process, from the bases previously existing in the state of silicates, or indirectly, by reactions between magnesian and alkaline carbonates formed during the decay, and the calcic salts of the early ocean. The chemical genesis of the lime carbonate must evidently precede its assimilation by organisms. It was, in fact, thus shown, as the result of a great number of observations, that fossil sea-waters (mineral waters), representing the ocean of Paleozoic and even of Mesozoic times, contained large proportions of calcic chloride, such as are required by this theory.[21] The relations of these reactions when "this decay of alkaliferous silicates is sub-aërial," as set forth in 1859 and 1863, will be found discussed at length in the volume of essays above named on pages 23–31, and page 108.

§ 15. I further proceeded at that time to consider the proportions between the alkalies and the alumina in the various characteristic minerals of crystalline rocks, noting the decrease in the former which is seen when silicates like orthoclase and albite are compared with micas like muscovite, and with silicates like cyanite, pyrophyllite and staurolite. The conclusion was then reached that "the chemical and mineralogical constitution of different systems of rocks must vary with their antiquity," and that "it now remains to find in their comparative study a guide to their respective ages;" in which connection a comparison was then attempted between the older gneisses and the newer crystalline schists. A further application of this principle was essayed in 1878, when the progres-

[19] Geol. Journ., London, xv, 488–496.
[20] Geol. Soc. Journ., Dublin, x, 85–95.
[21] Hunt: Chem. and Geol. Essays, pp. 41, 108, 117–121.

sive elimination of the alkalies from the aluminiferous rocks of the eozoic groups was shown by comparing the mineralogical composition of the Laurentian with the Huronian, Montalban and Taconian crystalline schists.[22]

§ 16. It should here be noted that decayed feldspars, even when these are reduced to the condition of clays, have not, in most cases, lost the whole of their alkalies. This is well illustrated in a series of analyses by Mr. E. T. Sweet, of the kaolinized granitic gneisses of Wisconsin, to be noticed farther on (§ 31). From these analyses it appears that the levigated clays from these decayed rocks still hold, in repeated examples, from two- to three-hundredths or more of alkalies, the potash predominating.[23]

§ 17. It would follow from the considerations advanced above, that the decay of crystalline rocks is an indispensable preliminary to the formation of limestone, and that the earliest silicated rock must have contained no carbonates whatever. There are many reasons for doubting whether this veritable primary system is known to us, but it will be remembered that at the base of the Laurentian, as seen on the Ottawa River, there is a vast and unknown thickness of red and gray granitoid hornblendic gneiss, apparently destitute of limestones, and underlying the great series of somewhat similar gneisses interstratified with limestones with graphite, iron-oxyds and quartzites, which were, as early as 1847, described by the Canadian geological survey as "a separate group of metamorphic strata," characterized by these lithological differences. Logan, however, supposed the two groups to be conformable, and they were in 1854 both included under the common name of Laurentian (afterwards the Lower Laurentian of Logan).

In a subsequent review of the subject in 1878, I designated the lower as the Ottawa group, and the upper group as the Grenville series.[24] It was this latter group which had been carefully studied and mapped by Logan and his assistants, and which has served as the type of the Laurentian system. I have since, in a paper read before the American Association for the Advancement of Science, in 1879,[25] noticed the probable nonconformability of this Laurentian system with the underlying or pre-Laurentian gneiss, and the possible relations of the latter to the fundamental or Lewisian gneiss of Scotland, and the Bojian gneiss of Bavaria.

[22] Second Geological Survey of Pa.: Azoic Rocks, Rep. E. p. 210.

[23] See for these, Irving on the Mineral Resources of Wisconsin, Proc. Amer. Inst. M. Engineers, vol. viii, p. 305. For other analyses, see Geo. H. Cook, Geol. Survey of New Jersey, Report on Clays, 1878.

[24] Azoic Rocks, pp. 64, 148, 154–156.

[25] The pre-Cambrian Rocks of Europe and America compared. Amer. Jour. Sci., xix, pp. 270, 275, 281; also Geol. Mag., Jan. 1882, p. 38, and Bull. Soc. Géol. de France, x, 26.

§ 18. The existence, in the Laurentian series, of limestones, not less than that of iron-ores and of graphite, pointing to the existence of land and of vegetation during the deposition of the Laurentian, forces us to conclude to a process of sub-aërial decay of the more ancient gneisses in that far-off period. Such a process must have been continued in later times to give the materials for the aluminiferous sediments of the newer eozoic groups, and we might therefore hope to find in the latter bowlders or pebbles of more ancient gneisses, such as are met with among the products of sub-aërial decay in later deposits. Remarkable examples of such rounded masses, alike of Montalban, Huronian and Laurentian or pre-Laurentian types are found abundantly in the very ancient pre-Cambrian (Keweenian), conglomerates on Lake Superior, as I have elsewhere described.[26] Not less striking examples of rounded masses of older gneisses occur in the Huronian series in many localities, particularly on Lake Temiscaming, where are great beds of conglomerate made up chiefly of gneiss bowlders.[27] I have elsewhere noticed a specimen in my possession which shows a perfectly well-defined and rounded pebble of finely granular white limestone, measuring an inch in its greatest diameter, enclosed in a laminated hornblendic gneiss from Grafton County, New Hampshire. Slices cut from the specimen for the microscope show a strong adhesion between the limestone and the quartz and feldspar of the matrix, without however any evidence of chemical change at the contact.[28]

§ 19. The rounded masses and pebbles of gneiss found abundantly in several localities imbedded in the pre-Cambrian micaceous schists of the Saxon Erzgebirge are not less remarkable examples of the same kind. I had in 1881 the opportunity of examining with Dr. Credner a large collection of these, which consist chiefly of types of various kinds of gneiss resembling those of the Laurentian series as seen in North America and in the Alps. These Saxon mica-schists, with their associated gneisses passing into granulites or leptynites, have all the characteristics of the Montalban or newer gneissic series of North America and of the Alps, to which I have elsewhere compared them in two communications[29] wherein are noticed the above-mentioned conglomerates, which had been previously studied in much detail by Sauer[30] in 1879. No one who sees these accumulations of rounded masses of gneiss and other crystalline rocks entering into conglomerates at the various horizons above named, can fail to be struck with their close resemblance with

[26] Hunt, Azoic Rocks, pp. 78, 230.
[27] Geology of Canada, 1863, p. 50.
[28] Bull. Soc. Géol. de France, [3] x, 27.
[29] Geol. Magazine, Jan. 1882, p. 39, and Bull. Soc. Géol. de France, x, 26.
[30] Zeitschrift f. d. ges. Naturwiss, Band lii.

those which are to be found either in the glacial or other modern deposits, or lying *in situ* as undecayed rounded masses in the midst of decomposed rocks. It is difficult to resist the conclusion that these rounded masses of the eozoic ages must have been formed under conditions not unlike those which gave rise to their more modern representatives.

§ 20. The various considerations above presented thus led the writer in 1873 to assign to the beginning of the process of rock-decay an antiquity compared with which the time that has elapsed since the drift-period is to be regarded as of short duration. It was, however, then suggested by him that a climate and atmospheric conditions unlike those of modern times might have favored the process in the earlier ages. Further evidence was soon forthcoming both of the former spread of this decay over northern regions and of its great antiquity.

In 1874 I was called to examine the condition of the great tunnel then recently opened through the Hoosac Mountain in western Massachusetts, my report on which was published by the General Court of the State;[31] while a note on the observations therein made which have a bearing on the present inquiry, was presented to the American Institute of Mining Engineers in October, 1874.[32]

§ 21. As there explained, the gneissic rock of Hoosac mountain, at the west end of the tunnel, 700 feet above the sea, is completely decayed, the feldspar being converted into kaolin for a distance of several hundred feet eastward along the line of the tunnel. The gneiss on the crest of the mountain, 2,000 feet above the sea, and on the eastern slope, on the contrary, wherever exposed, presents the rounded surfaces common throughout the region, often marked by glacial striæ, and without any appearance of decay. The softening and decomposition of the highly inclined strata of gneiss in the tunnel were described as complete for a distance of 600 feet from the west portal, where the floor of the tunnel is 200 feet from the surface, and were partial at 1,000 feet, where it is 230 feet below; while farther in, at 1,200 feet, an included bed of limonite, doubtless of epigenic origin, showed that the solvent and oxydizing action of atmospheric waters had penetrated to a depth of more than 300 feet from the present surface. At the western entrance to the tunnel the gneiss is immediately succeeded by the crystalline limestone and quartzite of the Taconian (Lower Taconic) series, the decayed rocks apparently coming from beneath the limestone. It was evident that this great mass of decayed gneiss at the western base of Hoosac Mountain is but a portion of a once wide-spread mantle of similar materials

[31] House Document No. 9, 1875.
[32] Proc. Amer. Inst. M. Engineers, iii, 187.

which has escaped the action that denuded and striated the surface of the other parts of the mountain.

§ 22. Numerous examples of similar remaining portions of decayed feldspathic rock have been observed farther southward, as in northwestern Connecticut (described in § 7), and among the Laurentian rocks of the South Mountain in Pennsylvania, north of the Schuylkill. One of these decayed portions, at Siesholtzville, Penn., was seen in 1875, where a bed of magnetite, at that time mined, was found to overlie at a high angle a mass of granitoid gneiss completely kaolinized, but apparently protected from erosion by the incumbent iron-ore.

In another example in the same region, about two miles south of Allentown, Penn., the Primal sandstone was found resting for a little distance on the Laurentian gneiss, here much decayed. Where this had been exposed in a recent cutting (in 1875) the reddish feldspathic rock, still retaining its color and its gneissic structure, though kaolinized, contained numerous "bowlders of decomposition," from three to twelve inches in diameter, consisting of undecayed gneiss, the laminated structure of which was clearly continuous with that seen in the enclosing decayed mass. These bowlders, still *in situ*, spheroidal in form, and often with pitted surfaces, are identical with those found in the drift near by, on the southeast slope of the hill, and are very different in outline from the half-angular forms of adjacent sandstone blocks. This gneiss rock, lying decayed in place, would, unless examined in fresh cuttings, be readily mistaken for the drift of the vicinity, which has evidently been derived from it.

§ 23. In my earlier notices of the decayed Montalban rocks of the Blue Ridge in North Carolina, I had described a mantle of from fifty to one hundred feet or more of decayed material, but this according to the late Professor W. B. Rogers, sometimes exceeds two hundred feet, a thickness approaching to that observed at the western base of Hoosac Mountain. I have since noticed the decay of the Montalban rocks near Atlanta in Georgia, where, with local exceptions of undecayed areas (as in Stone Mountain) the decomposition is more or less complete, in many places, to a depth of fifty feet. Here, as elsewhere, the more massive rocks include nuclear masses of undecayed material. The decayed highly hornblendic gneiss of Atlanta, though still retaining considerable coherence, has lost about two-thirds of its weight, the specific gravity of unchanged portions being 2·97—3·08, while that of the decayed material is reduced to 1·20, and even, for some specimens, to less than 1·0.[33] The decomposed gneiss in this region is, in some cases, sufficiently coherent to furnish blocks for certain purposes of

[33] Azoic Rocks, p. 250.5

construction, such as the walls of rude chimneys, but at the surface it readily disintegrates, yielding a strong red soil, often used as a brick-clay. The decayed mica-schists of the Montalban series, which still retain their micaceous aspect, have been called hydro-mica schists, though distinct from those of the Taconian, with which they have been confounded.

§ 24. The relations of the large deposits of cupriferous iron-pyrites found in the rocks of the Blue Ridge, to the general process of decay, was discussed by the writer in 1873,[34] after a study of the copper-mines opened in Carroll Co., Va., in Ashe Co., N. C., and in Polk Co., Tenn.[34] These ore-deposits were described as in each case in rocks of the Montalban group—the newer gneisses and mica-schists—and as constituting veins or lenticular masses of posterior origin, consisting essentially of pyrite, pyrrhotine and chalcopyrite. The agent which kaolinized the enclosing rocks, also oxidized the sulphurets, removing the sulphur and the copper, and converting the residue into limonite, which, in a vertical lode in Ashe Co., N. C., was found to extend to depths of from forty to seventy feet. Beneath the oxidized portion is found in all cases the unchanged pyritous mass, seldom carrying more than four or five hundredths of copper. The limonites thus generated were for some years smelted for iron, both in Virginia and in Tennessee, before they were discovered to be *gossans* at the outcrops of cupriferous pyrites-lodes. Between the unchanged pyrites and the limonite there is often found in favorable conditions an accumulation known as black ore, consisting of imperfectly crystalline sulphurets, rich in copper, and sometimes approaching to bornite in composition, occasionally with red oxide and native copper, the whole doubtless reduced from the oxidized and dissolved copper brought from above.

§ 25. The crystalline Eozoic rocks of various ages in the more northern parts of the continent contain, as is well known, many deposits of cupriferous pyritous ores, both in veins and beds which, like the enclosing strata, are undecayed, showing that the process of oxidation, like that of kaolinization, has been a very gradual one, going back to remote ages. We have seen from the observations in the southern United States that the oxidation of the sulphids, their conversion into limonites, and the removal therefrom by solution of the copper went on *pari passu* with the decay of the including rocks, and hence preceded their erosion. The copper thus dissolved was, as I have suggested, again deposited in rocks at the time in process of formation. The chief part of the iron being left behind, a veritable concentration of the copper would thereby be effected,

[34] Proc. Amer. Inst. M. Engineers, ii, 123, and this Journal, vi, 305: see also Chem. and Geol. Essays, pp. 217, 250.

and we should expect to find it separated on reduction as rich sulphides, or as native copper. In accordance with this view, it was said in an essay on The Geognostical Relations of the Metals, in February, 1873,[35] that certain deposits of such copper-sulphids found chiefly in limestones, probably of Cambrian age (Quebec group), which, in the province of Quebec, as at Acton and Durham, lie along the northwest border of the crystalline Huronian belt, might be formed from "the results of oxidation of the cupriferous beds which abound in the crystalline schists of these mountains, from which the dissolved metal accumulated in basins at their foot," as suggested by Murchison with regard to the cupriferous Permian strata near the crystalline schists of the Ural Mountains. "To a like process," it was said, "we may perhaps ascribe the rich deposits of native copper in the Keweenaw amygdaloids and conglomerates which rest upon the ancient Huronian schists."

§ 26. The farther extension of this view to the Mesozoic sandstones of Connecticut, New Jersey and Pennsylvania, well known to be very often impregnated with copper disseminated in the form of sulphides, sometimes associated with organic remains, is obvious. It is to be noticed that the strata in question are generally deposited directly upon Eozoic rocks, from the ruins of which they were formed, and that these, in our hypothesis, furnished the dissolved copper from which the disseminated ores were derived. If this view be admitted we have farther and independent evidence that the decay of the Eozoic rocks, with that of their contained cupriferous sulphurets, was going on in that pre-Cambrian period in which the Keweenian series was accumulated, and was still active in Mesozoic time.

§ 27. Not less striking examples of rock-decay are seen in the great Appalachian valley, of which Hoosac Mountain, the South Mountain and the Blue Ridge form parts of the eastern rim. Therein, as is well known, large quantities of limonite are mined, from New England to Alabama. This ore, as well as its accompanying manganese-oxide, is clearly of epigenic origin, and is, in most cases, still imbedded in ancient and highly inclined clayey strata derived from the sub-aërial decay *in situ* of the schists which accompany the dolomites and quartzites of the Primal and Auroral (Taconian) series. These ores have been formed by the transformation in place of included masses of pyrites and of carbonates of iron and manganese.[36] The evidences of the pyritic origin of many of these limonites is similar to that for those of the Blue Ridge (§ 24), namely, their association with unchanged pyrites. An example of this is seen in the so-called copperas mine at Breinigs-

[35] Proc. Amer. Inst. M. Engineers, i, 341.
[36] Azoic Rocks, pp. 201–203.

ville, near Trexlertown, Penn., long ago described by H. D. Rogers,[37] where large quantities of pyrites have been mined from the same openings which yield limonite, some of which I found still retaining the imitative forms of the adjacent pyrites, (from which Rogers had inferred a conversion of limonite into pyrites,) while the waters of the mine, like those of others in the region, were charged with sulphuric acid and with iron-sulphate. Another remarkable locality, where pyrites replaces the limonite in depth, was visible in 1875 at Seitzinger's mine, near Reading, Penn., and other similar cases are reported in the vicinity; while at Salona in the Nittany valley the association of pyrites with limonite at this same geological horizon has also been noticed.

§ 28. The association of siderite or iron-carbonate with the limonites of the Appalachian valley is well known east of the Hudson in New York and Massachusetts. This mineral is often manganesian and passes into nearly pure rhodocrosite. Examples of the association of siderite with limonite are also seen, among other localities, near Hackettstown, New Jersey, and near Hanover, York County, Pennsylvania. These carbonates, or at least the limonite and manganese-oxide derived from them, are found in close association with pyritous deposits, as we have seen near Trexlertown. In like manner pyrites and siderite as is well known, often occur side be side, in the coal-measures.

§ 29. I have elsewhere considered the change in siderite under the action of oxydizing atmospheric waters, which proceeds like that in feldspathic rocks, from without inwards, and is necessarily accompanied with considerable diminution of volume, which, in the conversion of a siderite of specific gravity 3·6 into a limonite of the same density, would equal 19·5 per cent.

"The evidences of this contraction may be seen in the structure of the limonite derived from siderite, which often forms a porous or spongy mass. In the case, however, of nodules or blocks of solid ore, the conversion beginning at the outside of the mass, an external layer of compact limonite is formed, and then another within this, and still another, till the change is complete. The void space resulting from contraction is then found betewen the layers, which are arranged like the coats of an onion; or sometimes wholly at the center, where a cavity will be formed, holding in many cases, more or less clay or sand, the impurities of the carbonate which have been separated in the process of conversion into limonite. In this way are formed the hollow masses sometimes known as bomb-shell ore, [which occasionally include nuclei of unchanged siderite.] Their structure

[37] Geology of Pennsylvania, i, 265.

will generally serve to distinguish the sideritic from the pyritic limonites."[38]

In the paper just quoted I have also considered the change of volume which should accompany the conversion of pyrites into limonite, a process generally complicated by the loss of a part of the iron as a soluble sulphate.

§ 30. Portions of the contorted and often highly inclined schistose strata enclosing the limonite ores in the Appalachian valley, are still found but partially decayed, and while some are converted to depths of 100 feet or more into white or variously colored clays, others retain more or less of their original texture. From the presence in some of these of considerable quantities of a hydrous micaceous mineral, having the composition of damourite, they have been called damourite-slates. There are many reasons for believing that these ancient rocks were thus folded and were decomposed before the deposition of the Trenton and Chazy limestones, which rest upon them in the outlying or western valleys of the Appalachian region, alike in Pennsylvania and in Alabama.[39]

§ 31. Prof. Lesley, in discussing the history of the limonites of the Appalachian valley, has fallen into an error with regard to my view of their origin. Referring in 1876 to the opinions expressed in my paper of 1873, (already noticed in § 13), touching the decayed crystalline rocks of the Blue Ridge, that "the iron-oxide from these has been in great part dissolved out by subsequent processes, and was the source of the immense deposits of hydrous iron-ores" in question, he supposes me to "conjecture that the ores lying along the eastern edge of the Shenandoah valley had been washed into it from or across the Blue Ridge." This Lesley properly qualifies as an "absurd conclusion," since it does not explain the origin of the limonites found in the back or central valleys, a hundred miles or more to the west of the Blue Ridge; and declares that had R. S. M. Jackson continued his geological studies, "he would have published a satisfactory refutation of this surface-drainage theory of the brown hematites."[40]

[38] The Genesis of certain Iron Ores, read before the Amer. Assoc. Adv. Science, Boston, 1880: see *Canadian Naturalist*, for Dec. 1880, vol. ix. p. 434.

[39] The fact of the existence at various points in the Appalachian valley of beds of limonite interstratified in Tertiary clays with lignite, as at Brandon, Vermont, must not be overlooked. First recognized by Edward Hitchcock, and subsequently noticed by Lesley in 1864, the later observations of Prime, Lewis and others, show the presence of these ores and clays with lignites at various points in Pennsylvania and in Alabama, as well as in Vermont. These are but fragments of what were probably once extended deposits, and although of geological interest as resulting from resolution and re-arrangement in Tertiary time, of a portion of the ancient decayed strata of the valley, are of comparatively little economic importance. (See H. C. Lewis, Proc. Acad. Nat. Sci. Philadelphia, Oct. 27, 1879.

[40] Second Geol. Survey of Penn., Report A, p. 83.

§ 32. Those who have read what I had written on the subject previous to 1876, and especially my discussion of the origin of these ores in 1874,[41] are aware that I have never advocated any such theory. I have, it is true, endeavored to find in the insoluble products of decay of these ancient crystalline rocks, the source not only of the clays and sands of the succeeding sediments, but of their contained iron, whether diffused or accumulated in ore-masses. I have, however, at the same time, always maintained that the ores associated with the so-called Primal and Auroral rocks of the Appalachian basin, like those of the higher horizons, up to the coal-measures inclusive, were deposits contemporaneous with the strata in which the valleys were subsequently excavated; and that save in some cases where, as in the Clinton beds, it was apparently deposited as peroxide, the iron was accumulated in the form of carbonate, and more rarely of sulphid; from the alteration of both of which, *in situ*, the limonites have been formed. This view, which as I then showed, was that advocated by C. U. Shepard, in 1837, for the limonites of western New England, was the same as that put forward in 1838, by R. S. M. Jackson himself, who maintained, as stated in the language of Prof. Lesley, "that the ore belonged to the stratified limestone beds themselves, and had been set free from them by chemical and mechanical decomposition." This history was clear to Dr. Persifor Frazer, who, having remarked that "the theory of alteration *in situ* of various iron-minerals resulting in the formation of many of these limonites, advanced by C. U. Shepard, and ably discussed and adopted by Dr. T. Sterry Hunt, cannot be disregarded in seeking the cause which produced these limonites," adds, "in 1838, and independently of Prof. Shepard's observations, Dr. R. S. M. Jackson reported to Prof. H. D. Rogers, substantially the same conclusion from the study of the limonites of Center and Huntingdon counties."[42]

§ 33. This same view in fact was well stated by Lesley himself in 1864, when he said "the brown-hematite ore-deposits of Mount Alto follow the edge of the slates and sandy limestones," and are "but the residues of these beds after decomposition and dissolution; the honey-combed and altered edges" of the slates and limestones themselves, "after the lime has been washed out of them, and their carbonated and sulphuretted iron has been hydrated and peroxidized; the slates having formed the red and white clays." He further described at one locality of the region in question "an outcrop of almost unchanged blue carbonate of iron and lime, several feet thick * *

[41] Proc. Amer. Institute Mining Engineers, iii, pp. 418–421.
[42] Second Geological Survey of Penn., Report C, p. 143.

and evidently in part changing into honey-combed brown hematite ore."[43]

§ 34. In 1867, Mr. Benjamin Smith Lyman, expressed similar views in his account of the limonites of Smyth County, Virginia, found lying below the limestones of No. II (Auroral), where many localities "show the ore unmistakably in regular beds conformable to the other rocks." He at the same time supposed that some of these ore-deposits are, like one noticed in Wythe County, Virginia, due to "the weathering of the upper part of a fissure-vein of iron-pyrites," but maintains that the ores, with such exceptions as this, were "deposited in regular beds of greater or less extent and thickness, at the same time with the other rocks," and from the presence in the limonite of occasional masses of carbonate of iron, concludes that it was originally deposited in this condition."[44]

§ 35. But while it is apparent that the ores in question now found imbedded in clays resulting from the decomposition *in situ* of ancient schists, were previous to that decay enclosed therein as massive siderite, or pyrites, we must not overlook the evidences that in certain cases a process of segregation of diffused iron-oxide has played an important part, alike in ancient and in modern times, in the genesis of limonites. Setting aside, as not relevant to our present inquiry, the formation of bog iron-ores, and ochers, which are directly deposited from ferrous solutions by peroxidation and precipitation, we here recall the contribution to the theory of the origin of imbedded iron-ores made by the late William B. Rogers.

The ferrous carbonate found in the rocks of the coal-measures, has, as he has endeavored to show, been generated from diffused ferric oxide by a process of reduction, carbonation and solution, through waters charged with organic matters from vegetable decay; the carbonate of iron thus formed remaining in some cases diffused through the sediments, and in others becoming concentrated by accretion.[45]

§ 36. This view is to be supplemented by the consideration that carbonated solutions of ferrous oxide formed as above (and often containing organic acids), may, by reacting with beds of carbonate of lime, effect a gradual replacement of the latter by carbonate of iron.[46] The transformation of diffused

[43] Amer. Philos. Soc. Proc., ix, p. 471–475.

[44] Proc. Amer. Assoc. Adv. Science, 1867, p. 114.

[45] Geological Survey of Penn., 1858, ii, 757.

[46] J. Ville found one liter of carbonated water at the ordinary pressure to hold in solution at 20° C. 1·142 grams of ferrous carbonate, and at 15° C. 1·390 grams. From these solutions neutral alkaline carbonates readily throw down the ferrous carbonate, themselves passing to the state of bicarbonates; and carbonates of lime and magnesia produce the same effect though more slowly. (C. Rendus de l'Acad. des Sciences, Oct., 1881, vol. xciii, p. 443.) The present writer found recently precipitated ferrous carbonate to be temporarily much more soluble, under the

ferric oxide in sediments into massive limonite imbedded therein, is thus a two-fold process, involving first, the intervention of reducing solutions converting the peroxide into ferrous carbonate, and the concentration of the latter; and second, the change of this latter, through peroxidation and hydratation, into limonite.

It is evident that the first stage of the process thus indicated by Rogers as taking place in sediments as yet unconsolidated, may also be set up in the disintegrated ferriferous materials resulting from the sub-aërial decay of rocks, and still undisturbed; that is to say, that the infiltration of waters holding dissolved organic matter may give rise in the decomposed mass to concretions of ferrous carbonate, which are subsequently changed into limonite. In this way, a concentration may be effected, through which rocks originally containing a small portion of diffused iron-oxide come to include masses of limonite Illustrations of this process are sometimes seen in the decay of impure limestones or dolomites containing, as is often the case, some ferrous carbonate, in the residuum of which we find the iron accumulated in the shape of crusts or layers of limonite.

§ 37. An instructive example of an analogous process is seen in the limonite which on Staten Island, New York, is found imbedded in a layer of brownish earthy material, sometimes attaining a thickness of twelve feet, which rests immediately upon the serpentine-rock of the region, into which it graduates, and from the sub-aërial decay of which it has evidently been derived, the lower portion of the earthy matrix still preserving the peculiar jointed structure of the underlying serpentine. This decomposed material, though including botryoidal crusts, geodes and concretionary grains of limonite, with occasional druses of chalcedony and of quartz crystals, retains considerable coherence.

The source of this limonite seems to have been the iron-oxide liberated by the decay of the ferriferous serpentine, and the proportion of ore in the superjacent mass shows a direct relation to the color and apparent proportion of iron-silicate in the serpentine beneath. This limonite, which is now mined to a considerable extent, contains, as several analyses have shown, from one to two-hundredths of chromic oxide, which is also known to be present in small amount in the serpentine. An impure argillaceous specimen containing only 59·63 of ferric oxide yielded the writer 2·81 of chromic oxide in a condition readily soluble in chlorhydric acid.

§ 38. Dr. N. L. Britton, of the School of Mines of Columbia

above conditions, yielding supersaturated solutions, which inclose vessels spontaneously deposit, after many hours, a large part of the carbonate in a crystalline condition.

College, in whose company I lately had an opportunity of visiting this interesting locality, published in 1880 a geological map with sections and a description of Staten Island.[47] He therein shows that the earthy material in which the limonite is imbedded is confined to the tops of certain hills of serpentine, being absent alike from other similar hills adjacent, and from intervening valleys cut into the serpentine, and he has connected this distribution of the ore-bearing stratum with the facts of the local glaciation of the region, to which he has devoted much attention. It is I think evident that the decay of the serpentine, and the concentration in the residuum, of its iron in the form of limonite, was a process anterior to the glacial erosion, and that the ore-banks are areas of the decayed material which escaped this action.

§ 39. Turning now to the valley of the Mississippi, we find that Pumpelly in his geological survey of Missouri, showed in 1873 that the decay *in situ* of granitic rocks and of quartziferous porphyry has left great rounded blocks of these crystalline rocks, while the conversion of the porphyry into clay, and its subsequent removal, has liberated included veins or masses of crystalline hematite, giving rise to an accumulation of detrital iron-ore, such as, at the well-known Iron Mountain, forms a covering over the surface of the hill of porphyry. From the presence of stratified deposits of this detrital ore in the ancient Cambrian strata around the base of the hill, Pumpelly inferred that the decay of the porphyry was already complete to a considerable depth at this early period.[48] His observations and deductions were not known to me when, in the same year, I published my conclusions as to the great antiquity and the universality of the process of rock-decay.

§ 40. Proceeding from Missouri northward, we find that in Minnesota, as shown by C. A. White[49] in 1870, and by N. H. Winchell in 1874, the ancient granitoid rocks, when protected by Cretaceous strata, support a kaolinized layer of considerable thickness.[50] In Wisconsin, a similar condition of things is found beneath the Potsdam sandstone in the central part of the State, as described by Irving in 1876,[51] in an essay which is a valuable contribution to the literature of kaolin, and contains many analyses of the decayed rocks of the region by Mr. E. T. Sweet, which have been already referred to, § 16. Further details of the same region and its kaolins, with analyses as before, were given by Irving in an essay in 1880 on the

[47] Annals New York Acad. Sciences, vol. ii, part 6.
[48] Geology of Missouri; Report on Iron Ores and Coal Fields, pp. 8-12.
[49] Geology of Iowa, i, 124.
[50] Second Annual Rep. Geol. Minnesota, pp. 162, 166, 207; also Hunt, Chem. and Geol. Essays, p. 250.
[51] Trans. Wisconsin Academy, etc., iii, 13.

Mineral Resources of Wisconsin.[52] In Jackson and Wood counties, where the crystalline (Laurentian) rocks are covered by a thin sheet of Potsdam sandstone, the river-valleys, cutting through this, expose the kaolin, which "occupies its original position, retaining sometimes the structure of the unaltered rock." This is derived from the decay *in situ* of certain bands, which passing downward, graduate into unaltered feldspathic rock. Save where this mantle of decayed material has been protected by the Paleozoic sandstone, the crystalline rocks are there seen for the most part in an undecayed condition, evidently, as Irving remarks, from the removal of the decayed material by "the denuding action of the drift." In some portions of the driftless area of this region the unprotected gneisses still retain their mantle of kaolinized material.

§ 41. From the facts before us, it is clear that the decay of the Eozoic crystalline rocks was already far advanced in pre-Cambrian times. I am informed that similar evidence is afforded in Sweden by the presence of decomposed rock beneath Cambrian strata. Prof. A. Geikie has moreover shown that the sculpturing of the gneiss rocks of western Scotland, a process which I have maintained to be dependent on previous sub-aërial decay, was effected before the deposition of the Cambrian sandstones, which there rest upon ancient *roches moutonnées.*[53]

§ 42. It might be supposed, from their stability under ordinary atmospheric influences in regions protected by vegetation, that all such portions of decayed Eozoic rocks as still exist in driftless or in protected areas date from the dawn of Paleozoic time, did we not know that the same processes of decay have been active in subsequent ages, as is shown by the decay of eruptive rocks of later periods. An example of this, which shows at the same time the little progress made in the process of decay since the drift-period, is seen in Canada, at Montreal, where, to the south of Mount Royal, the nearly horizontal beds of the impure Trenton limestone are found in sheltered places, deeply decayed and porous from the removal of their carbonate of lime, and are moreover traversed by dykes of dolerite and other feldspathic rocks, themselves decayed to considerable depths; while near by, and especially to the north of the mountain, where glaciation did its work of removing alike decayed aqueous and igneous rocks, the eroded surfaces of both of these are found hard and comparatively unchanged beneath a thin layer of soil and vegetation, as described by J. W. Dawson.

Another instance is afforded by a dyke intersecting the

[52] Proc. Amer. Inst. M. Engineers, viii, 103.
[53] Nature, August 26, 1880, p. 403.

Potsdam sandstone in this vicinity, which is found to be converted to a depth of twenty feet or more into a plastic highly aluminous clay, which, from the presence of portions of titanium and chromium is, we may conjecture, derived from a doleritic rock.[54]

§ 43. Rigaud Mountain, an igneous mass rising through the Potsdam sandstone, and occupying several square miles on the south side of the Ottawa, near its confluence with the St. Lawrence, is probably of Paleozoic age, and consists in large part of a reddish granitoid orthoclase rock. Considerable areas of its surface, lying lower than the surrounding crests of the mountain, are covered to a depth of seven feet or more, in places, with well rounded bowlders from three to eighteen inches in diameter, consisting wholly of the rock of the mountain, with the exception of a few masses of sandstone. The plains so covered attain in their higher parts an elevation of about 280 feet above the Ottawa, but slope gently both to the south and the north. The bowlders are very rare on the north slope of the mountain, and at its northern base, but are abundant on the southern slope and in the low-lying clay-covered plains to the southward.[55] These well-rounded masses, spread over so much of the mountain are apparently bowlders of decomposition, still *in situ*, having escaped the denuding agents of the drift-period.

§ 44. Examples of more recent sub-aërial decay of crystalline rocks, under peculiarly favorable conditions, were in 1880 described independently by Jos. LeConte and myself, in the auriferous Pliocene gravel of California. The pebbles of feldspathic and hornblendic rocks occurring in the portions below drainage-level—the so-called *blue gravel*—are unaltered, while above that level the similar pebbles, exposed to the action of meteoric waters, are more or less completely kaolinized, exfoliating, becoming earthy in texture, rusty in color, and in some cases converted into a clayey mass. The pyrites so abundant in the blue gravel, has, in these upper portions, or so-called *red gravel*, been oxidized, and the accompanying lignites have been silicified, and often incrusted with crystallized quartz, from silica liberated in the process of rock-decay through the infiltration of surface-waters.[56]

§ 45. To the porosity of the gravel, and the great amount of surface thus exposed, is to be added the influence of carbonic acid from the decaying lignite, the carbon of which is oxidized as the process of silicification goes on. The amount of carbonic dioxide in the air of certain drift-mines in these auriferous

[54] Report Geol. Survey of Canada, 1878–79, H., p. 7.
[55] Geology of Canada, p. 896.
[56] LeConte, this Journal, xix, 177; Hunt, ibid, xix, 371.

gravels is so great that candles will not burn therein. Mr. D. T. Hughes of San Francisco, a well-known mining engineer, to whose careful scientific observations I have been much indebted, informs me that in the case of a drift-mine 300 feet below the surface, in Table Mountain, Tuolumne Co., Cal., where the foulness of the air was especially remarked, he satisfied himself by appropriate tests of the presence in the air of a large proportion of carbonic-dioxide. If, as there is reason to suppose, the amount of this element in our atmosphere was somewhat greater in former ages than at present, we have in these gravels an illustration of its influence in promoting the decay of silicated rocks. It is not improbable that the sulphuric acid generated by the oxidation of the pyrites present in these gravels may also have aided in the process.

§ 46. The slight evidences of decomposition to be seen in the crystalline rocks of thoroughly glaciated regions, as well as in transported bowlders, makes it probable that the seemingly rapid progress of decay, occasionally observed on exposure, of similar rocks in other regions, sometimes appealed to as evidence of a decomposition now going on, is really but the mechanical disintegration of masses already partially kaolinized in former ages. The crumbling of certain apparently unaltered granitoid rocks, in which the feldspar remains bright and hard, should be distinguished from that which follows chemical decomposition. Such disintegration, due apparently to changes of temperature[57] and the action of frost, is, however, important, and deserves farther study from the fact that materials apparently of similar origin enter into the composition of many derived rocks. Lava-flows are, it has been observed, subject to comparatively rapid sub-aërial decay, but these rock-surfaces differ widely in texture as well as in composition from most crystalline rocks.

§ 47. An essay by Professor Pumpelly on Secular Rock-Disintegration, read before the National Academy of Sciences in April, 1878,[58] is a very valuable contribution to the subject before us. He cites therein my conclusions as to the great antiquity and the universality of the process of rock-decay (to which his own observations in Missouri have contributed im-

[57] In this connection I venture to recall the attention of geologists to a phenomenon already described both by Dr. Shaler and myself, apparently due to superficial alternations of temperature on certain crystalline rocks, which have resulted in establishing in them, to a considerable depth, a series of rifts or divisional planes parallel to the present surface, which are well known to quarrymen. Instances of this abound; besides those noticed by me in this Journal for July, 1870 (vol. i, p. 89), may be mentioned the gneiss on the opposite slopes of Rolleston Hill, Fitchburg, Mass., and that of Stone Mountain near Atlanta, Ga.; also a remarkable example of comparatively thin horizontal plates at the outcrop of beds of nearly vertical micaceous gneiss in the vicinity of Worcester, Mass.

[58] This Journal, xvii, 133–144.

portant data) and also as to the final removal of decomposed material from northeastern America in the time of the glacial drift. He further notes the little attention hitherto given to the subject of sub-aërial decay, and points out its importance in connection with great problems in dynamical geology. The view that this process of rock-decay is "a necessary preliminary to glacial and erosive action, which removed already softened materials," receives from Professor Pumpelly an extended discussion and application. He proceeds to consider the removal and the re-arrangement of these softened materials by three different agencies. First, the encroachment of the sea upon a subsiding region of decayed rocks; second, the action of land-glaciers, in which he points out that the great mass of disintegrated and water-impregnated rock would become frozen, and included, as it were, in the glacier, sharing in its movements and forming thus a ground-moraine.[59]

§ 48. To these modes, with which are to be included the ordinary action of rivers and floods, all acting on the peripheral areas of continents, he adds, for the central areas, removed from these agencies, and rendered desert by geographical conditions, the action of the winds. By these, the decayed rock, according to Pumpelly's extension of the ingenious hypothesis of Richthofen, will be separated into the fine material of the lœss, on the one hand, and the sand and gravel of the desert steppes on the other. He thus explains the condition of the crystalline rocks in northern Asia, from which the decayed mantle has been removed not by glacial but by aërial agencies; while the similar rocks in southern Asia, as in Brazil and the southern United States, are still deeply covered with the products of their own decomposition.

§ 49. Pumpelly further remarks that the surface of the undecayed rock to be laid bare by erosion is necessarily an irregular one, the inequalities depending not upon its original differences in hardness, but upon its resistance to decay under the influence of atmospheric waters. The effect of fractures, joints, veins and dykes in the rock in favoring or retarding the action of this agent would be manifested by still further irregularities of the plane limiting the decomposition of the rock in depth.

[59] Other agencies than ice may produce a similar displacement of decayed material. Belt, in 1874, in his Naturalist in Nicaragua (page 94), describes a movement of the mantle of decayed crystalline rock on hill-sides in that country, as due to land-slides in wet weather. The layer of ground and "reworked" decayed material resting on the gneiss found by Hartt in Brazil (Scientific Results of a Journey, etc., pp. 28, 573) and referred by him to glaciation, may perhaps be a similar phenomenon. More recently, Kerr, in 1879, has described the results of a slow downward motion of the decomposed surface on mountain-sides in North Carolina, as due to the alternate freezing and thawing of the contained water. To this displaced and modified layer, which resembles that produced by glacial action, he gives the name of *frost-drift*. (Proc. Amer. Inst. M. Engineers, viii, 462.)

Thus the rounded surfaces and the closed rock-basins so often observed in glaciated regions of crystalline rocks are seen to be but the natural results of the process of rock-decay, which preceded and prepared the way for denudation.

§ 50. Similar views as to glacial erosion have since been advocated by Nathorst, and more lately by Reusch, who, in a memoir on the geology of Corsica, presented to the Geological Society of France, in November, 1882,[60] has described the disintegration of the granitic region of Corsica to a depth of several meters, giving to the surface smooth slopes instead of the bold escarpments seen in like rocks in Scandinavia. He notes in these disintegrated rocks in Corsica enclosed balls or ellipsoidal masses, fresh in appearance, but like in composition and in structure to the enclosing rock, which, when detached, have been taken for erratic blocks. With this region, he contrasts the similar rocks near Christiania, in Norway, with hard, rounded surfaces, marked by glacial scratches, where it is difficult to find any trace of superficial decay. He does not believe that the ice of the Glacial period removed any considerable portion of the hard rock, to form fiords, valleys, etc., but supposes "a profound disintegration of the Scandinavian rocks before the Glacial period," and conceives the present relief to "represent the surface of the unaltered syenite after the removal by the glaciers of all the decomposed part."

The salient rock-masses of the Norwegian coast are, like the fiords, arranged in a north and south direction, and this, according to Reusch, corresponds with that of fissures, more or less nearly vertical, which traverse the rock, and, as he well remarks, prepared the way for its disintegration in depth, the extent of which would depend upon differences in the nature of the rock. Many of the lake-basins of this region were, according to him, formed through the removal by glaciers of the decayed material from depressions, while others are due to the action of moraines, serving as dykes.

§ 52. It is difficult to state more clearly the consequences which follow from the conception that the decomposition of rocks is "a necessary preliminary to glacial action and erosion, which removed previously softened materials." Reusch, however, seems, from some misconception, to regard this pre-glacial disintegration of the rocks as distinct from kaolinization, of which the crumbling of the granites in Corsica, as in other regions, doubtless represents an incipient stage, such as we meet with in depth, in regions where the superficial and more completely decayed portions have been removed (§ 46).

[60] Bull. Soc. Géol. de France, xi, 62–67.

Conclusions.

§ 53. The points insisted upon in this paper may be thus briefly resumed:—

1st. The evidence afforded by recent geological studies in America, and elsewhere, of the universality and antiquity of the sub-aërial decay both of silicated crystalline rocks and of calcareous rocks, and of its great extent in pre-Cambrian times.

2d. The fact that the materials resulting from this decay are preserved *in situ* in regions where they have been protected from denudation by overlying strata alike of Cambrian and of more recent periods; or, in the absence of these coverings, by the position of the decayed materials with reference to denuding agents, as in driftless regions, or in places sheltered from erosion, as in the Appalachian and St. Lawrence valleys.

3d. That this process of decay, though continuous through later geological ages, has, under ordinary conditions, been insignificant in amount since the glacial period, for the reason that the time which has since elapsed is small when compared with previous periods, and also probably on account of changed atmospheric conditions in the later time.

4th. That this process of decay has furnished the materials not only for the clays, sands and iron-oxides from the beginning of Paleozoic time to the present, but also for the corresponding rocks of Eozoic time, which have been formed from the older feldspathic rocks by the partial loss of protoxide-bases. The bases thus separated from crystalline silicated rocks have been the source, directly and indirectly, of all limestones and carbonated rocks, and have, moreover, caused profound secular changes in the constitution of the ocean's waters. The decay of sulphuretted ores in the Eozoic rocks has given rise to oxidized iron-ores, and also to deposits of rich copper ores in various geological horizons.

5th. That the rounded masses of crystalline rock left in the process of decay constitute not only the bowlders of the drift, but, judging from analogy, the similar masses in conglomerates of various ages, going back to Eozoic time; and that not only the forms of these detached masses, but the outlines of eroded regions of crystalline rocks, were determined by the preceding process of sub-aërial decay of these rocks.

ART. XXIV.—*On Mr. Glazebrook's Paper on the Aberration of Concave Gratings;* by H. A. ROWLAND.

IN the June number of the Philosophical Magazine, Mr. R. T. Glazebrook has considered the aberration of the concave grating and arrives at the conclusion that the ones which I have hitherto made are too wide for their radius of curvature. As I had published nothing but a preliminary notice of the grating at that time, Mr. Glazebrook had not then seen my paper on the subject, of which I gave an abstract at the London Physical Society in November last. In this paper I arrive at the conclusion that there is practically no aberration and that in this respect there is nothing further to be desired.

The reason of this discrepancy is not far to seek. Mr. Glazebrook assumes that the spaces are equal on the arc of the circle. But I do not rule them in this manner; but the equal spaces are equal along the *chord* of the arc. Again, the surface is not cylindrical, but spherical.

These two errors entirely destroy the value of the paper as far as my gratings are concerned, for it only applies to a theoretical grating, ruled in an entirely different manner from my own, and on a different form of surface.

I am very much surprised to see the method given near the end of the paper for constructing aplanatic gratings on any surface, for this is the method by which I discovered the concave grating originally, and the figure is the same as I put on the blackboard at the meeting of the Physical Society in November last. I say I am surprised, for Mr. Glazebrook's paper was read at the Physical Society, where I had given the same method a few months before, and yet it passed without comment. Indeed, I have given the same method many times at various scientific societies of my own country. However, as Mr. Glazebrook was not present at the meeting referred to, he is entirely without blame in the matter.

ART. XXV.—*On the Stibnite from Japan;* by EDWARD S. DANA.

THE Yale Museum has recently come into possession of a series of specimens of crystallized stibnite from Japan which are of so remarkable a character as to deserve a detailed description. In the size and beauty of the crystals, and in the great complexity of their form, the Japanese stibnite far outrivals the specimens of the same species from other localities, and takes a first place among metallic minerals. The specimens here described formed part of a lot received by Mr. L. Stadtmüller of this city from a correspondent residing in Japan. Other specimens, also of unusual excellence, were earlier re-

ceived from Messrs. Ward and Howell of Rochester, which had been obtained by Mr. Ward when in Japan, a year or two since. To what extent specimens from the same source have found their way into European collections, the author is not informed.

The locality, which has furnished these remarkable stibnites, is stated to be Mount Kosang near Seijo, on the island of Jaegimeken Kannaizu (Shikoku) in South Japan. The antimony mines have been worked for a considerable period, and the crystallized specimens are highly valued by the natives as ornaments; Mr. Ward speaks of having observed them mounted in flower pots and used to adorn the dwellings.

The remarkable size of these Japanese specimens is the feature which first attracts the attention. A simple group consists of two prismatic crystals with vertical axes nearly parallel; the longer of the two measures twenty-two inches, and the other fifteen inches in length, the thickness varies from one and one-half to two inches. The prismatic planes are deeply striated; the free extremity in each case is well terminated by brilliantly polished planes. Another very fine specimen consists of half a dozen crystals, grouped closely together in slightly diverging positions so that they are united for a considerable part of their length. The total length of the central crystal of the group is twenty-one inches, and the combined width is six inches; the individual crystals have a width of one and one-quarter to two inches. The prismatic planes in this group are smooth and have the luster of highly polished steel; the crystals are for the most part well terminated. Another isolated crystal has a length of sixteen inches, and there are several finely developed detached crystals ranging from six to nine inches in length. The finest group of crystals has a length of eleven inches and a height of ten and one-half inches. The crystals forming it diverge widely above and below from the central mass, consisting of the same mineral sprinkled over with small quartz crystals, so that they stand free from each other. There are about twenty crystals in the group measuring from three to six inches in length, together with numerous smaller ones. Another group measures eight by nine inches and consists of diverging and interlacing crystals two to six inches long. In other groups the crystals form a comparatively even surface not projecting outward as is more common. A large mass partly massive with imperfect crystallization has a length of sixteen and one-half inches, a height of eight and a width of four inches. In addition to the above there are numerous smaller specimens consisting of groups of highly modified brilliant crystals from half an inch to two or three inches in length.

The specimens in the Yale Museum are especially mentioned

here because they include the finest of which the writer has any knowledge. There are, however, in Mr. Stadtmüller's hands numerous other specimens which also deserve mention, being hardly inferior in size or beauty to those which have been described. It would be difficult to name another case on record in which metallic crystallization has taken place on so grand a scale.

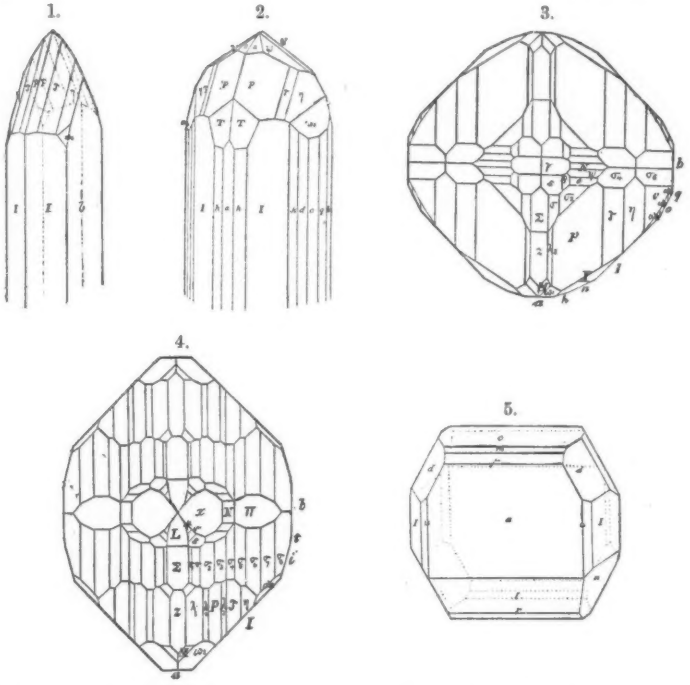
The luster of these crystals of stibnite is an important element in their beauty. In all the better specimens this luster is very brilliant, giving the crystalline faces a polish which is rarely excelled. The luster of these natural planes is not less splendent than that of a fresh surface obtained by the perfect cleavage parallel to the brachypinacoid, and can be compared only with that of highly polished steel, as for example the surface of a razor blade. To what extent the brilliancy of the luster will be dimmed by prolonged exposure to daylight can hardly be predicted, but the appearance of older specimens from other localities would make it seem inevitable that this brilliancy should be gradually lost.

From a scientific point of view the complexity of form observed among the Japanese stibnites is their most remarkable character. There have certainly not many cases been observed in which the crystals of a species from a single locality show as many as seventy distinct and well-defined forms.* Previous to 1864 but sixteen planes had been identified. Krenner in his excellent monograph of the species† added twenty-eight new planes, and Seligmann‡ added one more, thus making the list forty-five in all. Of these forty-five planes, thirty have been observed on the Japanese crystals, and in addition to them *forty new planes* have been determined, thus increasing the list to *eighty-five*. This list could be considerably enlarged if the planes admitting of only doubtful determination were to be added. The habit of the majority of the crystals, especially of the larger ones, is tolerably constant. They are always prismatic, elongated in the direction of the vertical axis, and are often more or less flattened parallel to the brachypinacoid; the prismatic planes are generally numerous and often follow each other in oscillatory combinations. The termination of the free extremity is generally formed by the zone between the brachypinacoid $b(010)$ and the unit macrodome $z(101)$, and the three commonest planes are $p(111)$, $\tau(343)$ and $\gamma(353)$, of which the plane τ has usually the larger development. Together with these the new plane $\omega_2(5{\cdot}10{\cdot}3)$ is ordinarily present. This occurrence of the zone mentioned con-

* Bücking enumerates 172 on the epidote from the Untersulzbachthal, Z. Kryst., ii, 321, 1878.

† Ber. Ak. Wien, li, Dec. 9, 1864. ‡ Jahrb. Min., 1880, i, 135.

taining the pyramidal planes 121, 353, 343, 676, 111, 656, 323, 313, is the common feature of the crystals of the locality. In other crystals the zone between the brachypinacoid (010) and the macrodome $\Sigma(203)$, containing the pyramidal planes 2·12·3, 283, 273, 263, 253, 243, 233, 223, 213, 629, all but one of which are new, is strongly developed; as many as nine of the planes in this zone have been observed in a single crystal.



Figures 1 and 2 show common forms, and the projections on the basal planes given in figures 3 and 4 show the development of the two zones mentioned, as also of several other characteristic zones. In some cases the crystals are spear-shaped being sharpened off by very steep pyramidal planes; several of these do not admit of exact determination being rough and rounded, but several of them can be made out, as $T(521)$, $A(361)$, and so on.

The most complex of the crystals are generally small, varying in thickness from $\frac{1}{4}$ mm. to $1\frac{1}{2}$ mm.; occasional large crystals, however, show a considerable number of planes, these being sometimes so rounded into each other as not to admit of determination. The crystal from which figure 4 was drawn

has a length of 7 inches, the planes are mostly sharp and distinct; another crystal, remarkable for its symmetry, but much rounded on the edges, for the opportunity to examine which the writer is indebted to Mr. Clarence S. Bement of Philadelphia, had a length of $7\frac{1}{2}$ inches and a thickness of $1\frac{1}{2}$ (macrodiagonal) and 2 inches (brachydiagonal).

The bending over of the crystals in the direction of the macrodiagonal axis is a very common peculiarity of these crystals, and seems to be characteristic of the species. This has been described at length by Krenner, who mentions crystals so bent as to form a complete ring. With the Japanese crystals this bending is generally confined to the termination, but in some cases it has gone so far that the edge is bent between two adjacent pyramidal planes (p or τ) so as to make a right angle with itself. Sometimes this results in a simple rounding over of the pyramidal planes, but more commonly they are separated into a series of successive apparent planes. This irregularity is so common that it is not easy to find crystals, even among the smaller individuals, which are quite free from it. Thus in a specimen consisting of a group of small crystals almost all are found to be more or less curved at the extremities. Fortunately this makes itself manifest at once, so that there is no danger of mistaking false planes produced by this irregularity for true crystalline faces. The cause of this common peculiarity it is hard to explain. In the case of some of the larger individuals it would seem that it might have been produced by mechanical means, and, though this is not generally true, in all cases it appears as if produced subsequent to the formation of the crystal. More rarely the slender prismatic crystals have a cork-screw-like twist.

As Krenner (l. c.) has observed, it requires only a slight pressure in the direction of the axis b to produce this bending of the crystals. The ease with which it takes place will be appreciated from this circumstance—a slight pressure, accidentally given to a small crystal which was being adjusted for measurement on the goniometer, served to transform it from a symmetrical crystal, capable of giving accurate measurements, into one with curved extremity, quite useless for this purpose. Seligmann (l. c.) has observed that parallel to the base there is often a "gleitfläche" produced by the molecular sliding perpendicular to the brachypinacoid, and Mügge* has more recently called attention to similar phenomena. The natural prismatic crystals are often terminated by a striated surface, having the position of the basal plane, but doubtless to be regarded only as a "gleitfläche."

The exact determination of the axial ratio for the Japanese

* Jahrb. Min., 1883, ii, 19.

stibnites was made more difficult in consequence of the irregularity which has just been described. Many crystals of faultless luster, which seemed capable of giving excellent angles, were found to be quite unreliable because of an incipient bending of the character described. In cases where this difficulty did not exist the results were very satisfactory. A number of crystals were subjected to careful measurement and the results obtained from the best one of these deserve to be stated in detail. It showed the planes $p(111)$, $\tau(343)$, $\gamma(353)$ and $\omega_3(5{\cdot}10{\cdot}3)$, all giving excellent reflections; there were also present several smaller planes and a number of prisms, but they did not give results accurate enough to serve the purpose in view. As fundamental (supplement) angles were obtained

$$353 \wedge 3\bar{5}3 = 99° 39' 0'' \text{ and } 353 \wedge \bar{3}53 = 55° 1' 0''$$

The following comparison between the measured angles and those calculated from the above data will show that the angles assumed are as accurate as could be expected, and that the crystal is unusually free from irregularity.

	Measured.	Calculated.		Measured.	Calculated.
$111 \wedge 1\bar{1}1$	70° 48′	70° 48′	$111 \wedge \bar{1}11$	71° 24′	71° 24′
$\bar{1}11 \wedge \bar{1}\bar{1}1$	70° 49′		$1\bar{1}1 \wedge \bar{1}\bar{1}1$	71° 23½′	
$343 \wedge 3\bar{4}\bar{3}$	86° 55′	86° 55′	$343 \wedge \bar{3}43$	62° 37′	62° 37′
$\bar{3}43 \wedge \bar{3}\bar{4}\bar{3}$	86° 55′		$3\bar{4}3 \wedge \bar{3}\bar{4}3$	62° 37½′	
$353 \wedge 3\bar{5}\bar{3}$	99° 39′*	99° 39′	$353 \wedge \bar{3}53$	55° 1′*	55° 1′
$\bar{3}53 \wedge \bar{3}\bar{5}3$	99° 39′		$3\bar{5}3 \wedge \bar{3}\bar{5}3$	55° 1½′	
$5{\cdot}10{\cdot}3 \quad 5{\cdot}\bar{1}\bar{0}{\cdot}3$	119° 27′	119° 27′	$5{\cdot}10{\cdot}3 \wedge \bar{5}{\cdot}10{\cdot}3$	51° 34′	51° 34½′
$\bar{5}{\cdot}10{\cdot}3 \quad \bar{5}{\cdot}\bar{1}\bar{0}{\cdot}3$	119° 27′		$5{\cdot}\bar{1}0{\cdot}3 \wedge \bar{5}{\cdot}\bar{1}0{\cdot}3$	51° 34′	
$111 \wedge \bar{1}\bar{1}1$	110° 36′	110° 38′	$353 \wedge \bar{3}\bar{5}3$	126° 26′	126° 28′
$1\bar{1}1 \wedge \bar{1}11$	110° 38′		$3\bar{5}3 \wedge \bar{3}53$	126° 28′	
$343 \wedge \bar{3}\bar{4}\bar{3}$	119° 5′	119° 5′	$5{\cdot}10{\cdot}3 \wedge \bar{5}{\cdot}\bar{1}0{\cdot}3$	150° 29½′	150° 30′
$3\bar{4}3 \wedge \bar{3}43$	119° 6′		$5{\cdot}\bar{1}0{\cdot}3 \wedge \bar{5}{\cdot}10{\cdot}3$	150° 30′	

The above measurements show that a considerable degree of confidence may be placed in the axial ratio deduced from the fundamental angles selected. This is

$$\breve{a} : \bar{b} : \dot{c} = 1 : 1{\cdot}00749 : 1{\cdot}02550.$$

The prismatic angle $I \wedge I\,(110 \wedge 1\bar{1}0) = 89° 34'{\cdot}3$.

The axial ratio obtained by Krenner differs somewhat from this, he giving—

$$111 \wedge 1\bar{1}1 = 70° 33'{\cdot}4 \quad 111 \wedge \bar{1}11 = 71° 39'{\cdot}6, \text{ and } 110 \wedge 1\bar{1}0 = 89° 5'{\cdot}8.$$

The following is a list of the planes which have been observed on the Japanese stibnite, those which are new being marked by an asterisk (*). The planes are given in the order of the vertical zones in which they occur:

Pinacoids i-$\bar{1}$ (100, a), i-$\breve{1}$ (010, b); prisms i-$\bar{3}$ (310, h), i-$\bar{2}$ (210, n), i-$\frac{5}{2}$ (320, ι)*, I (110, m), i-$\frac{5}{3}$ (560, κ)*, i-$\frac{1}{3}$ (340, r), i-$\frac{3}{2}$ (230, d), i-$\frac{5}{3}$ (350, l), i-$\breve{2}$ (120, o), i-$\frac{5}{2}$ (250, χ)*, i-$\breve{3}$ (130, q), i-$\breve{4}$ (140, i), i-$\breve{5}$ (150, t), i-$\breve{6}$ (160, ϑ)*, i-$\breve{7}$ (170, θ)*; macrodomes $\frac{1}{3}$-$\bar{\imath}$ (103, L), $\frac{2}{3}$-$\bar{\imath}$ (203, Σ)*, 1-$\bar{\imath}$ (101, z), 9-$\bar{\imath}$ (901, Φ)*; brachydomes $\frac{1}{3}$-$\breve{\imath}$ (013, γ), $\frac{1}{2}$-$\breve{\imath}$ (012, x), $\frac{2}{3}$-$\breve{\imath}$ (023, N), 1-$\breve{\imath}$ (011, u), 2-$\breve{\imath}$ (021, Π)*, 4-$\breve{\imath}$ (041, Y)*; pyramids $\frac{1}{4}$ (114, μ)*, $\frac{2}{7}$ (227, ν)*, $\frac{1}{3}$ (113, s), $\frac{2}{3}$ (223, σ_2)*, 1 (111, p), 3 (331, ξ); macro-pyramids $\frac{2}{9}$-$\bar{4}$ (829, Ψ)*, $\frac{1}{3}$-$\bar{1}$ (413, M); $\frac{2}{3}$-$\bar{5}$ (629, σ_1)*, 1-$\bar{3}$ (313, λ_1)*; $\frac{5}{2}$-$\frac{5}{2}$ (523, ω_1)*, 5-$\frac{5}{2}$ (521, T)*; $\frac{5}{3}$-$\bar{2}$ (213, σ); 1-$\frac{3}{2}$ (323, λ_2)*, 4-$\frac{3}{2}$ (431, X)*; 1-$\frac{5}{2}$ (656, λ_3)*; brachy-pyramids $\frac{1}{9}$-$\frac{1}{9}$ (9·10·3, Z)*, $\frac{7}{6}$-$\frac{7}{6}$ (676, β); $\frac{4}{3}$-$\frac{5}{3}$ (4·5·12, δ)*; $\frac{2}{3}$-$\frac{3}{4}$ (246, Γ)*, $\frac{4}{3}$-$\frac{3}{3}$ (343, τ), $\frac{2}{3}$-$\frac{3}{3}$ (15·20·3, D)*; 1-$\frac{3}{2}$ (233, σ_3)*, $\frac{1}{3}$-$\frac{3}{2}$ (20·30·9, W)*, 5-$\frac{3}{2}$ (10·15·3, E)*, $\frac{5}{3}$-$\frac{5}{3}$ (583, ω_2)*; $\frac{2}{5}$-$\frac{5}{3}$ (15·25·6, F)*, $\frac{5}{3}$-$\frac{5}{3}$ (353, η); $\frac{2}{3}$-$\bar{2}$ (123, e), $\frac{1}{3}$-$\bar{2}$ (243, σ_4)*, 2-$\bar{2}$ (121, v), $\frac{1}{3}$-$\bar{2}$ (5·10·3, ω_3)*, 6-$\bar{2}$ (361, A); $\frac{1}{2}$-$\frac{1}{6}$ (5·11·3, ω_4)*; 1-$\frac{5}{4}$ (255, H)*, $\frac{5}{3}$-$\frac{5}{2}$ (253, σ_5)*, 2-$\breve{3}$ (263, σ_6)*; $\frac{1}{2}$-$\breve{3}$ (10·30·9, V)*, $\frac{3}{2}$-$\frac{7}{2}$ (273, σ_7)*; $\frac{2}{3}$-$\breve{4}$ (146, ψ), 1-$\breve{4}$ (144, G)*, $\frac{2}{3}$-$\breve{4}$ (283, σ_8)*, 4-$\breve{6}$ (2·12·3, σ_9)*.

The above list includes 70 planes, of which 40 are new to the species. In addition to the above there have been observed 15 additional planes, as given below; of these the basal plane, given by Haüy, must be considered as doubtful; Hessenberg gives the planes w and ρ, Seligmann observed g, and the remainder are given by Krenner.

O (001, c)?; i-$\frac{3}{3}$ (430, k); $\frac{1}{6}$-$\bar{\imath}$ (106, R), $\frac{1}{2}$-$\bar{\imath}$ (102, y); $\frac{4}{3}$-$\breve{\imath}$ (043, Q), $\frac{5}{3}$-$\breve{\imath}$ (053, J), 3-$\breve{\imath}$ (031, $\jmath$), $\frac{9}{2}$-$\breve{\imath}$ (092, g); $\frac{1}{2}$ (112, π); $\frac{1}{2}$-$\bar{2}$ (214, f); 1-$\frac{3}{3}$ (434, a); 1-$\frac{6}{7}$ (878, ε), 3-$\breve{3}$ (131, w); $\frac{3}{3}$-$\breve{4}$ (143, ϕ); $\frac{5}{3}$-$\breve{5}$ (153, ρ).

In conclusion, I state here briefly the observations upon which the determinations of the new planes are based. The measured angles, though sufficient to determine the planes, could seldom be exactly obtained. In the *prismatic zone* the new planes were determined by angles measured on the brachypinacoid b (010), as follows: for ι (320) 56° 50′, required 56° 30½′; for $\varkappa$ (560) 40° 4′, required 40° 1′; for χ (250) 22° 9′, required 21° 57′; for ϑ (160) 9° 42′, required 9° 32′; for θ (170) 8° 21′, required 8° 11½′. The new *macrodomes* were determined by angles measured on the macropinacoid a (100), as follows: for Σ (203) 55° 40′, required 55° 38½′; for Φ (901) 6° 20′, required 6° 11′. The new *brachydomes* were determined by angles measured on the brachypinacoid b (010), as follows: for Π (021) 26° 20′, required 26° 9½′; for Y (041) 14°, required 13° 48′. In the zone of the unit pyramids three new planes were observed: μ (114) determined by the angle on I (110) = 70° 17′, required 70° 8′; ν (227) also in the zone with x (012) and Σ (203); and σ_2 (223) also in the zone with 203 and 010.

In the zone between 203 and 010 as many as 10 pyramidal planes were observed, all but one on a single crystal, and of these 9 are new. The measured angles on Σ (203) were for σ_1 (629) 10° 30′, for σ_2 (223) 29° 30′, for σ_3 (233) 40°, for σ_4

(243) 48° 1′, for σ_5 (253) 54° 17′, for σ_6 (263) 59° 7′, for σ_7 (273) 62° 55′, for σ_8 (283) 65° 10′. The corresponding calculated angles are respectively σ_1 10° 34½′, σ_2 29° 15½′, σ_3 40° 2½′, σ_4 48° 15′, σ_5 54° 28′, σ_6 59° 16′, σ_7 62° 58½′, σ_8 65° 57′. In addition, the plane σ_9 (2·12·3) was determined on another crystal, being in a horizontal zone with Y (041), and the angle 9° for 2·12·3 on 041 being given, calculated 9° 16′.

In the zone between z (101) and b (010) in which 8 planes have been previously determined, three new planes were observed; they were fixed by the angles on the brachypinacoid, viz: for λ_1 (313) 77°, required 76° 40½′; for λ_2 (323) 64° 30′, required 64° 39′; for λ_3 (656) 59° 30′, required 59° 22′. The common plane ω_3 (5·10·3) was determined by the measurements given in the table above; in the same horizontal zone (503 to 010) with it, three other planes were observed, viz: ω_1 (523) also in the zone I (110) to z (101), $\omega_1 \wedge I$=36° 30′, required 36° 6½′; also ω_2 (583) determined by the angle on b (010) 35° 31′, required 35° 0½′; ω_4 (5·11·3) which was also in the zone q (130) and η (353), the measured angle on b (010) was 27° 59′, required 27° 57′.

In the zone with a (100) and ω_3 (5·10·3), two planes were determined, viz: V (10·30·9) measured angle on ω_3=8°, required 7° 56′; and W (20·30·9) measured angle on ω_3=7°, required 7° 0′. In the zone with I (110), ω_3 (5·10·3) and σ_7 (273), three additional planes were determined, viz: D (15·20·3) measured angle on I (110)=10°, required 10° 32′; E (10·15·3) measured on I(110) 14° 30′, required 14° 35½′; F(15·25·6) measured on I (110) 19°, required 18° 2′. The measured angle of I (110) on ω_3 (5·10·3) was 23° 29½′, calculated 23° 29′. Of the remaining planes X (431) was in the zone I (110) to z (101) and the measured angle on I was 14°, required 13° 42′. The plane I (346) was in the zone N (023), ψ (146) σ_2 (223), the angle measured on N was 23° 20′, required 22° 58½′. The plane Ψ (829) was in the zone σ_1 (629) and a (100), the following angles were also measured $\Psi \wedge \sigma$ (203)=12° 30′, required 12° 23′; $\Psi \wedge 213$ 10°, required 9° 56′. The plane T(521) was determined by the following measurements: $T \wedge T$ ($_{521 \wedge 5\bar{2}1}$)=42° 15′, required 42° 34′; $T \wedge h$ (310) 11°, required 10° 48′; $T \wedge I$=31° 45′, required 32° 16′. The planes G (144) and H (255) were in the zone with u (011) and a (100), the angles measured on u were 10° and 15° 30′ required 10° 11′ and 16° 2′.

Since the above pages were written the writer has received from Mr. Stadtmüller, to whom he is otherwise much indebted, some additional material which promises to afford some new points; the study of this is necessarily deferred.

August 3, 1883.

ART. XXVI.—*Notes on the Volcanoes of Northern California, Oregon and Washington Territory;* by ARNOLD HAGUE and JOSEPH P. IDDINGS, of the U. S. Geological Survey.

DURING the autumn of 1870 the geologists attached to the Geological Exploration of the Fortieth Parallel made a preliminary reconnaissance of several of the extinct volcanic cones of Northern California, Oregon and Washington Territory for the purpose of planning detailed investigations of the principal volcanoes of the Sierra and Cascade Ranges. A further study of these volcanoes however was never undertaken, and although the explorers brought back most interesting geological and lithological material the results and observations of the work have never been published, with the exception of an announcement in this Journal for March, 1871, of "The discovery of actual glaciers on the mountains of the Pacific Slope," and a popular paper on "The volcanoes of the United States Pacific Coast," read by Mr. S. F. Emmons before the American Geographical Society, March 13th, 1877.

Among the more prominent peaks along this belt of volcanic cones may be mentioned Lassen's Peak and Mount Shasta in California; Mount Pitt, Three Sisters, Mount Jefferson and Mount Hood in Oregon; and Mounts St. Helens, Adams, Rainier and Baker in Washington Territory. From this long line of volcanoes the geologists of the Fortieth Parallel Survey selected for the purpose of exploration the four peaks which, from their size, position and geological relations, might be taken as typical of the chain. Mr. Clarence King explored the two great cones of California; at the same time, Mr. S. F. Emmons undertook the examination of Mount Rainier, while Mt. Hood was visited by one of the writers of the present article. The collections which they made at that time were deposited in the cabinet of the survey.

Lassen's Peak is situated in California just north of the fortieth parallel of latitude, where the continuity of the bold crest of the Sierra Nevada Range breaks down and is replaced by lower and less regular ridges. From Lassen's Peak this magnificent chain of volcanoes extends northward at irregular intervals for nearly five hundred miles. The principal volcanoes follow in general the axial lines of the Sierra and Cascade Ranges, breaking out either along the main line of upheaval or at short distances to the westward. Volcanic extrusions along fissure lines and flows of lava of greater or less extent unite the main peaks, forming a nearly continuous belt of igneous rocks.

Mount Rainier is the grandest of all the volcanoes of the Northwest and forms the most prominent topographical object in Washington Territory, rising proudly above all other peaks, and towering far above the crest of the Cascade Range which lies about twenty miles to the eastward. The surface features of the western portion of the territory have been greatly modified by the great lava-flows of the volcano, and no less than four important rivers of the territory rise among the glaciers of the mountain: the Nisqually, Puyallup and White Rivers, which flow into Puget Sound, and the Cowlitz which, running in a southwesterly direction pours into the Columbia. Snow and ice cover the top of the volcano, reaching downward for five or six thousand feet, while with the most marked contrast the broad base of the mountain supports a dark, dense forest vegetation of great grandeur. The summit of Mount Rainier is formed by three peaks, the highest situated to the eastward of the other two and separated from them by deep and nearly inaccessible gorges, although they attain within a few hundred feet of the same altitude. The main peak presents a perfect, circular cone with a crater about a quarter of a mile in diameter. The altitude of the peak as determined by the United States Coast Survey is 14,444 feet.

Mount Hood is situated directly on the crest of the Cascade Range, about twenty-five miles south of the Columbia River. It has an altitude of 11,225 feet above sea-level, rising about 6000 feet above the main range, but the long lava flows extending in every direction from the base of the volcano have buried beneath their mass nearly all remnants of preëxisting rocks. Mount Adams and Mount St. Helens, on the north side of the Columbia River, form with Mount Hood a triangle, the area of which has been the center of great volcanic activity. The summit of Mount Hood is a single peak, a portion of a rim of an ancient crater, opening to the south. The crater is about one-half a mile wide from east to west, the encircling wall for three-fifths of the circumference rising 450 feet above the snow and ice which fills the basin.

None of the volcanoes along this belt occupy so comparatively isolated a position as Mount Shasta, which stands upon an open plain with the neighboring hills and ridges many thousand feet lower. The great range of the Sierra has fallen away and is followed by low obscure ridges, confused and broken up by volcanic outbursts. The altitude of Mount Shasta is given at 14,440 feet above sea-level, and as the neighboring ridges rarely attain an altitude of over 3000 feet, the volcano presents an imposing spectacle, surpassed by few mountains in the world. As seen from the west the volcano presents a double cone, with the smaller built upon the flanks

of the larger one and about 2000 feet lower. The main cone possesses a very regular outline, with remarkably steep slopes of uniform angle. Around the broad base of Mount Shasta numerous lesser cones have broken out, offering a great variety of volcanic phenomena. One of these, which has been named Little Shasta, rises to more than 3000 feet above the neighboring valley. Seventy miles southeast of Mount Shasta, not far from the boundary between Nevada and California, occurs Lassen's Peak, lying, as already mentioned, along the direct line of the Sierras, where the granite of the main range has been abruptly broken down. The region has been the seat of great volcanic activity lasting through long periods of time, the present mountain forming but a remnant of former extrusions, and so far as geological interest is concerned is probably unsurpassed by any other mountain. Lassen's Peak, however, is by no means as conspicuous an object as many of the volcanoes, being surrounded by other cones of considerable elevation, all of them rising out of a great volcanic table. The altitude of Lassen's Peak is given at about 10,500 feet. It is a broad, irregularly shaped mountain with four prominent summits and abundant evidences on the slopes of comparatively recent extrusions of lava.

As the rocks brought back may be considered as representing the principal types of the ejected lavas from the different flows, a large number of thin sections have recently been prepared for the purpose of comparative study with the volcanic rocks of the Great Basin, and their microscopic examination has been followed up by chemical investigation. While a cursory examination of these rocks shows certain special characteristics in color, habit and form of crystals which in many cases easily identifies hand specimens with one or the other of the volcanoes, a comparative study of their mineralogical, structural and chemical features shows the closest identity in the nature of the ejected material from the four volcanoes. In their lithological characters they possess so many features in common that a general description might be given which would be applicable to them all.

These four great cones, which may be taken as typical of the chain, are all andesite volcanoes, with extrusions of basalt breaking out upon their slopes and along the edges of the plain extending in all directions for long distances. From the compact basic basalts of normal type to the more porous acidic andesites similar variations in mineral composition and minute details of structure are found at each of the volcanoes. This similarity holds good not only in macroscopic characters, but is still more marked in microscopic structure. In size, color and distribution of porphyritic crystals, in structure of groundmass,

in the nature of the glass base, and in the transitions from a nearly pure glass to a crystalline condition, many rocks from one volcano may be easily correlated with those from one or more of the other peaks.

Their similarity in chemical composition is strikingly shown by the following analyses of typical rocks from each of the four volcanoes. Nos. I, II, III, are taken from the report of the Geological Exploration of the 40th Parallel. No. IV, as well as nearly all the rest of the chemical work referred to in this paper, was done by Mr. P. W. Shimer under the supervision of Dr. Thomas M. Drown, in his laboratory at Easton.

TABLE I.

	I. Mt. Rainier.	II. Mt. Hood.	III. Mt. Shasta.	IV. Lassen's Peak.
SiO_2	61·62	63·28	60·44	62·94
Al_2O_3	16·86	17·96	18·12	18·14
Fe_2O_3		1·18		
FeO	6·61	3·16	5·16	3.82
CaO	6·57	5·34	6·43	6·28
MgO	2·17	2·50	3·43	3·06
Na_2O	3·93	3·81	4·09	3·83
K_2O	1·66	2·06	1·25	1·22
Ignition		0·12	0·89	0 60
				TiO_2 0·41
				P_2O_5 0·10
	99·42	100·04	99·79	100·40

While the rocks from these volcanoes in general present the closest resemblances, there is a wider range and a greater variety of structure in the more acidic types from Lassen's Peak and Mount Shasta. On the other hand, judging from the collections, the range in the character of the extrusions is most restricted at Mount Rainier.

All these rocks then may be classified under the following heads:

Basalt, composed of plagioclase, augite and olivine, as essential minerals.

Hypersthene-Andesite, having plagioclase, hypersthene and augite as essential minerals.

Hornblende-Andesite, with plagioclase, hornblende and pyroxene as essential minerals.

Dacite, composed of plagioclase, mica, hornblende and quartz as essential minerals.

Basalt is represented by but few hand specimens which belong in general to the type found throughout the great basin, that is, they are more or less dense rocks, sometimes quite vesicular, varying in color from dark to light gray, and occasionally mottled. They show no porphyritic crystals other

than olivine, and those only in small crystals. In thin section they appear to vary in degree of crystallization. The more coarsely crystalline have very uniform grain, and are composed of lath-shaped plagioclase feldspars with high extinction angles; irregular grains of light brownish green augite, and colorless olivine sometimes in porphyritic crystals with magnetite in minute crystals and particles aggregated in irregular patches, accompanied by a little glass that fills the interstices between the other minerals. The smaller grained varieties have a more porphyritic structure, and consist of a groundmass of lath-shaped plagioclase crystals, with augite and magnetite and glass base in varying proportions, through this are scattered small porphyritic plagioclases and olivine and occasionally augite.

Hypersthene-andesite.—The hand specimens of this rock are in general very porous, with rough surface and hackley fracture. They vary in color from blue-black to steel-gray, with red and reddish gray varieties. They also occur in all stages from thoroughly crystalline dense forms to almost white glassy pumice. For the most part they are crowded with very small porphyritic crystals of which the feldspars are the most noticeable, the Fe, Mg, silicates being more apparent in the lighter colored varieties. The thin sections show a striking uniformity in the nature and character of the porphyritic crystals, but great variation in the structure and condition of the ground mass, which affords a most interesting field for studying the gradations between a brown glass base and a holocrystalline groundmass. The porphyritic feldspars in the thin sections appear to be wholly plagioclase, no orthoclase having been recognized, they are very fresh and present between crossed Nicols a most beautiful zonal structure, and quite irregular bands of twining, which with sharply defined straight edges vary in length, breadth and numbers, and are formed both after the albite and pericline laws. Inclusions of glass are very abundant in some crystals and entirely wanting in others. When of comparatively large size they are scattered irregularly through the crystal, but when very minute they occur in aggregations that sometimes form zones at the margin or center of the feldspar. From the size of the symmetrical extinction angles observed it would appear that a part of the plagioclase is anorthite, but that for the most part the feldspar is labradorite or andesine, and such was found to be the case when the feldspars from the hypersthene pumice were analyzed chemically. (See analyses III and IV, table II.)

The Fe, Mg, silicate of this rock is pyroxene, partly hypersthene, partly augite, the hypersthene predominating. In thin section the latter is a light brown mineral with a tinge of green, which in polarized light shows a strong pleochroism, be-

ing green when the axis *c* is parallel to the principal plane of the polarizer and yellowish brown at right angles to it, of different intensities parallel to the *a* and *b* axes. It occurs in well developed crystals and in fragment, and sections parallel to *c* are often quite free from cleavage lines. Cross-sections show the pinacoids more strongly developed than the prism faces, and the prismatic cleavage more distinct than the pinacoidal. It frequently bears numerous glass inclusions and magnetite grains. It is very easily confounded in thin sections with augite in ordinary light, which with very similar outline is of a pale green color; but the two are more readily distinguished between crossed Nicols where the hypersthene shows orthorhombic extinction and less brilliant interference colors than the augite which besides has in general more or less inclined extinction. In order to demonstrate beyond all doubt by both chemical and optical tests that the strongly pleochroic pyroxene observed in so many thin sections was really orthorhombic and hypersthene, as had been supposed, it was desirable to isolate the mineral from all other constituents and examine it in a pure state. The rock selected for the purpose came from a long slope of Mt. Shasta designated on the label as a mud flow. It is a porous straw-colored pumice with a comparatively simple mineral composition and was chosen on account of the large amount of orthorhombic pyroxene which it contained and the ease with which it could probably be isolated. The pumice was largely composed of nearly colorless glass through which were scattered minute crystals of pyroxene and feldspar which under the microscope proved to be triclinic; there was a little apatite present, but neither hornblende nor mica could be detected. As the very friable pumice could easily be crushed between the fingers, although a very tedious operation, the greater part of the pyroxene was separated from the rest of the rock constituents without injury to the terminal faces of the minute crystals. The remainder of the pyroxene was then separated from the greater part of the feldspar and glass by means of the Thoulet solution of iodide of mercury in iodide of potassium. Under the microscope the isolated pyroxene was seen to consist of about 99 per cent of the strongly pleochroic brown mineral, the remainder consisting of light green augite. Adhering to the pyroxene were minute fragments of glass and a little feldspar which could not be removed without crushing the crystals. The separated mineral was then passed under the microscope and the augite carefully removed by hand. In order to free the mineral from glass and feldspar it was treated as described by M. Fouqué in his admirable work, "Santorin et ses Éruptions," with concentrated fluohydric acid, which completely decomposed the im-

purities. The white deposit of silica, owing to its low specific gravity, was easily removed by water and mechanical methods. This isolated pyroxene was found to consist of dark brown crystals in stout prisms bounded by two pinacoids, a prism and pyramid, and when rotated about the *c* axis on a needle point between crossed Nicols they showed the extinctions in the prism zone always parallel to that axis. Examined in convergent light the interference figure was that of a biaxial mineral with large angle between the optical axes and with a negative bisectrix perpendicular to the plane of the pinacoid, ($? \infty P \bar{\infty}$), the plane of the optical axes being parallel to the other pinacoid. It was therefore proved to be an orthorhombic mineral with negative optical character. The green augite which was separated from this had a slight pleochroism, was very free from inclusions, and when rotated between crossed Nicols showed its monoclinic character, the maximum extinction angles being 42° in the plane of the clinopinacoid. The interference figure seen in a section parallel to the orthopinacoid was a bar located a little to one side of the field of the microscope, showing an optical axis nearly at right angles to this pinacoid, the plane of the optical axes being parallel to the other pinacoid.

In the second column of the subjoined table is given an analysis of the orthorhombic pyroxene, which shows that the material analyzed was remarkably pure hypersthene without admixture of augite, the impurities being such as are derived from foreign inclusions within the crystals. These results show the mineral from the Mount Shasta pumice to agree more closely with the theoretical composition of hypersthene than that from Buffalo Peak in Colorado, as given by Whitman Cross,* or with that from Santorin as published by M. Fouqué.†

To the feldspar, hypersthene and augite of first consolidation in these hypersthene andesites must be added the largest grains of magnetite scattered through the rock. As remarked before, the character of these porphyritic minerals remains quite constant while the structure of the groundmass presents every possible degree of consolidation, from pure glass to a completely crystallized aggregation of magnetite, pyroxene, feldspar and quartz. In general the groundmass consists of more or less glass base, sometimes globulitic, at others pure, full of lath-shaped and rectangular feldspars, smaller pyroxene crystals and magnetite grains, which vary greatly in size in different specimens. The darker colored rocks have a groundmass rich in brown or globulitic glass with small microlites of feldspar and pyroxene; the lighter colored ones having colorless

* Bulletin of the United States Geological Survey, No. 1, 1883.
† Santorin et ses Éruptions, Paris, 1879.

glass with much larger microlites of feldspar and pyroxene and magnetite. The minuteness and intimate association of the minerals of such a groundmass renders a mechanical separation of them for chemical analysis impossible, and interferes also with a perfect isolation of the larger feldspars. But in the case of the pumice from which the hypersthene just described was extracted the groundmass is an almost pure glass, and as the microscope shows that the hypersthene was the first of the essential minerals to crystallize from the original magma, an analysis of the rock is of considerable interest. In the first column of table II is given a complete chemical analysis of the pumice which does not vary materially from the analyses of the more compact lavas given in table I. Lithologically it differs from the other rocks in being more porous and lighter in color as the iron is nearly all taken up by the hypersthene and a trace of magnetite. The phosphoric acid is accounted for by the presence of apatite. The titanic acid is probably associated with the magnetite. As shown by the analyses the trace of manganese is all concentrated in the hypersthene as well as the greater part of the iron and magnesia. After separating the heavier minerals from the feldspar and glass, the latter were subjected to the Thoulet solution in order to completely isolate the glass from feldspar. An amount of glass was finally obtained which gave optical tests of carrying very little if any feldspar. It was however a much more difficult task to free the feldspar from particles of adhering glass, and only after repeated trials was a product secured which contained a nearly pure feldspar. All attempts to determine two distinct feldspars by differences in specific gravity proved futile and it seems probable that the greater number of them belonged to one species. In volcanic rocks rich in glass base, containing minute feldspars it would seem nearly impossible to completely separate such species as labradorite and oligoclase. The difficulty is not so much owing to slight differences in specific gravity as to the impurities in the crystals, so that a labradorite rich in glass inclusions might readily be of less specific gravity than a pure oligoclase. Two separations of feldspathic material were obtained; one with specific gravity from 2·66 to 2·68 and the other from 2·64 to 2·66, analyses of which are given in columns III and IV. The two products are strikingly similar in composition and do not agree with any known species. In all probability they represent the same feldspar rendered more or less impure by foreign ingredients. Nevertheless the results are exceedingly interesting, showing so far as they go that the heavier portion is richer in lime and magnesia and carries somewhat more iron, while the lighter portion holds more silica and alkalies. As the original rock

carries considerable lime, of which very little is taken up by the pyroxene, it is reasonable to suppose that all the larger feldspars are labradorite mingled with others which may be andesine and oligoclase. An analysis of the glass which forms the base of the pumice is given under number V. It is highly siliceous, showing a falling off in alumina, the feldspar-making element which together with the lime had not entered into the first crystallizing mineral, hypersthene. On the other hand the analysis shows a considerable relative increase of alkalies with the greater part of the potassa of the original rock, which had not been taken up by the minerals which crystallized out concentrated here in the residual glass.

TABLE II.

	Pumice. I.	Hypersthene. II.	Feldspar. III.	Feldspar. IV.	Glass base. V.
SiO_2	62·00	50·33	56·41	56·95	69·94
Al_2O_3	17·84	0·57	27·39	27·47	15·63
FeO	4·40	22·00	0·69	*trace*	1·89
CaO	5·37	1·88	9·87	9·10	2·49
MgO	2·64	23·29	0·09	0·02	0·28
K_2O	1·47	----	0·36	0·48	2·85
Na_2O	4·29	----	5·43	5·78	3·83
MnO	*trace*	0·64	----	- --	----
TiO_2	0·17	----	----	----	----
P_2O_5	0·29	----	----	----	----
Ignition	1·66	----	---	----	3·25
	100·13	99·11	100·24	99·80	100·16

Specific gravity of III = 2·66 to 2·68. IV = 2·64 to 2·66. V = 2·29

Hornblende-Andesite.—The examples of hornblende-andesite are of two kinds; one which resembles the hypersthene-andesite very closely and is distinguished from it solely by the abundance of hornblende in porphyritic crystals; another that has a compact gray groundmass with large, brilliant, black hornblendes and has the same appearance as the celebrated domite from the Puy de Dôme in Southern France. The first mentioned variety is best described by saying that it has the same general habitus and microstructure as the lighter colored kinds of hypersthene-andesite and similar mineral constitution with the addition of a reddish-brown hornblende, in some specimens brownish-green, which in places has a small black border. This type of rock then is composed of plagioclase feldspar, hornblende, hypersthene, a little augite and magnetite, that are found in porphyritic crystals embedded in a groundmass of the same, generally with the exception of hornblende, with or without glass. The feldspars appear to be less basic than those in the hypersthene andesite, giving extinction angles corresponding to andesine. The second variety of hornblende andesite, which is represented only by hand specimens from Straw-

berry Valley near Mount Shasta, when in thin sections is seen to consist chiefly of a groundmass of lath-shaped feldspars, smaller pyroxene micro-crystals and a little magnetite with or without colorless glass, through which are scattered a few small porphyritic plagioclases and relatively very large hornblendes, which in some specimens are reddish brown, in others brownish green. They are occasionally surrounded by a border of magnetite and augite grains, which in some cases have entirely replaced the hornblende substance. There are no porphyritic pyroxene crystals; of the porphyritic feldspars, a few appear to be as basic as anorthite, a very interesting fact when the silica percentage of the rock, 65·27 per cent, is considered, and which may account for the small amount of pyroxene in the ground mass and for its being all hypersthene. A chemical analysis of the rock would probably show a relatively large amount of alumina.

Dacite.—A fourth type of rock occurs as an extreme volcanic outburst about four miles to the northwest of the highest point of Lassen's Peak, which for several reasons requires a detailed notice. Owing to the broken and rough nature of the place, the appropriate name of Chaos has been applied to the region. All geologists who have visited the place agree that it is one of the latest, if not the most recent extrusion from the peak, as is shown not only in the hot springs and in the constant escape of steam and gases, but in its relation to the surrounding rocks. The rock is not only quite different in mineral composition and structure from anything else in the collection from Lassen's Peak, but is quite unlike the rocks brought in from the other volcanoes. Baron von Richthofen, who visited the volcano during his studies upon the relative age of volcanic rocks, which he afterwards published in his very able work, "A Natural system of Volcanic Rocks," regarded this rock as one of great interest, and mentions the locality as a typical one for a variety of rhyolite which he named nevadite, or granitic rhyolite from its close resemblance to granite. He says, "geologically nevadite appears to have been produced as frequently by volcanic activity as by massive eruption. An interesting occurrence is that at Lassen's Peak, where it was first discovered by Prof. W. H. Brewer and Mr. Clarence King." A few years later Mr. King revisited the place and brought back the specimens upon which the present observations are based. Our investigations lead us to quite different results, and we can not regard the rock as in any sense entitled to be classed as a rhyolite, as we fail to find among the many sections of feldspar any determinable sanidine, an essential constituent of rhyolite. Upon a superficial examination the hand specimens bear a singularly close resemblance to granite, especially to the more

common types of the Sierra Nevada, but a closer scrutiny brings out a fundamental difference, as the rock is rich in glass base, through which the secreted minerals are scattered. The specimens vary from a moderately compact rock to others of a pumice-like character, the glass being drawn out in fine hairs or threads across the cavities and open spaces, giving it a porous appearance. It is a quartz-mica-hornblende-plagioclase rock and may be classed as a dacite, the quartz-bearing member of the andesite group, and it is the only rock in the collection in which quartz is so abundant as to be regarded as an essential constituent. All the thin sections of this rock examined under the microscope showed the closest identity in structure—a colorless glass full of gas cavities of all sizes, through which are found relatively few microscopic crystals of plagioclase, and hornblende with less mica, pyroxene, magnetite, apatite and zircon. This forms a porous ground mass which bears large porphyritic crystals of plagioclase, mica, hornblende and quartz, and very rarely pyroxene. Nine-tenths of the feldspars showed lines of striation, the remainder appearing to be brachypinacoidal sections of the same species, showing strong zonal structure. No sanidine was detected in any of the sections. The feldspars contain very large and abundant glass inclusions, some with as many as nine gas bubbles in one globule of glass. The mica is reddish brown in basal sections, with small angle between the optical axes. The hornblende is greenish and reddish brown and is without dark border. The pyroxene is both hypersthene and augite. Quartz that appears so abundantly in the hand specimens is seldom seen in thin section, as it is in cracked grains that drop out in grinding; when met with it is seen to contain only glass inclusions in di-hexahedral forms. The following chemical analysis of this dacite, given in column I, table III, shows it to be from 6 to 9 per cent richer in silica than the prevailing rocks of the four main cones.

TABLE III.

	I.	II.	III.
SiO_2	69·36	65·77	76·75
Al_2O_3	16·23	21·51	12·32
Fe_2O_3	0·88		
FeO	1·53	trace	1·36
CaO	3·17	5·72	1·18
MgO	1·34	0·00	0·00
Na_2O	4·06	5·92	3·55
K_2O	3·02	0·83	3·98
Ignition	0·45	0·34	0·54
	100·04	100·09	99·68

The analysis itself would indicate that the rock belonged to the dacites, for in addition to the increase in silica there is an

increase in the percentage of alkalies, principally of potassa, with a corresponding decrease of iron, lime and magnesia. If on the other hand we compare this analysis with the published and unpublished analyses of rhyolites from the Great Basin we find a relatively low percentage of alkalies and too large amount of lime, magnesia and iron. In other words it has the chemical composition of a dacite. To determine more accurately the composition of the feldspathic material, the feldspar and glass were separated from the heavier minerals by the Thoulet solution, and the products subjected several times to the same treatment until the separation was nearly complete. The result gave a glass nearly free from feldspar, and a feldspar with some glass particles, but regarded as not enough to vitiate the value of the analysis. In column II of the third table will be found the feldspar, and in column III the residual glass. The analyses show clearly that there could be but little if any sanidine present. The feldspar analyzed, although a little high in silica owing to the glass as an impurity, agrees closely with the analyses usually given for andesine. It may be a mixture of andesine and oligoclase. It will be seen that by far the greater part of the potassa of the rock remains concentrated in the glass, as is the case with the hypersthene-andesite pumice. In this case the potassa in the residual glass is in excess of the soda, while in the crystallized feldspar it bears to soda the proportion of about 1 : 7. To confirm if possible the results obtained by microscopic and chemical investigation upon the feldspars in the dacite, we picked out a number of crystals to test by Dr. Szabó's admirable and delicate method of determining feldspars in rocks by means of the color imparted under certain conditions to the flame of a Bunsen burner. For the application of this method we are greatly indebted to Dr. Szabó, who during his visit to this country a year ago kindly gave us practical instruction to enable us to carry out his tests. All feldspars examined gave the reactions for andesine or oligoclase, completely confirming the results obtained by other methods.

The four types of rocks just described, namely: basalt, hypersthene-andesite, hornblende-andesite and dacite exhibit, it is true, four well characterized groups, but they cannot be said to be sharply defined and distinct forms. Indeed between any two in the order named exist all possible intermediate varieties. Thus among porphyritic basalts are found those with diminishing olivine and increasing hypersthene which may equally well be called hypersthene-bearing basalts or olivine-bearing hypersthene-andesites. And right here it may be well to point out the relationship existing between hypersthene and olivine. A microscopic study of these intermediate rocks in conjunc-

tion with chemical determinations has shown that hypersthene is the substitute for olivine in rocks differing from basalt by a somewhat higher silica percentage, the former mineral being, as it is, simply the bi-silicate of the same Fe, Mg, elements. It is not strange then to find rocks of similar structure and appearance differing solely in the relative proportion of olivine and hypersthene, and passing by easy gradations from basalt to hypersthene-andesite.

Between hornblende-andesite and hypersthene-andesite occur varieties in which only a small amount of hornblende is found, and which with equal propriety might as hand specimens be considered as modifications of one or the other types.

In the same way forms are found intermediate between hornblende-andesite and dacite, whose proper connection only field observation can determine. It will be remarked that no mention has been made of augite-andesite; among the andesites in this collection from the volcanoes none have been found in which the predominating pyroxene is augite.

The foregoing general descriptions apply to the varieties of lava from whichever of the four great volcanoes they are found, and it only remains to point out what the varieties are that occur at each volcano as learned from the present collection. Mount Rainier is formed almost wholly of *hypersthene-andesite*, with different conditions of groundmass and accompanied by hornblende and olivine in places. The rocks from Mount Hood are olivine-bearing *hypersthene-andesite* approaching basalt; hornblende-bearing *hypersthene-andesites* and *hornblende-andesites*. From Mount Shasta were collected *basalts* both dense and porous and of varying shades of color; *hypersthene-andesites* in great variety, from compact to pumiceous and of many colors, some bearing more or less hornblende and presenting the transition forms to hornblende-andesite, which occurs in abundance. The variety resembling domite is from Sisson's Cone and Black Butte, Strawberry Valley near Mt. Shasta.

From Lassen's Peak have been brought in *basalt, hypersthene-andesite* with small amount of hornblende; *hornblende-andesite and dacite*. One variety of the hornblende-andesite has very small porphyritic crystals. A chemical analysis being given in table I, column IV. Another variety especially from what have been called the earlier and later flows, has quite large crystals of glassy-looking plagioclase, hornblende and some mica and less quartz. The rock from the later flow has fewer porphyritic crystals than that from the earlier one, and is accompanied by a variety of hornblende-andesite of most curious structure. It is a very porous evengrained mass composed of tabular plagioclases, hornblende and colorless glass,

the hornblende playing the same rôle as the augite of many diabases, its irregular form filling the spaces between well-developed plagioclase crystals, which in part appear to be anorthite and have crystallized before the hornblende. There is a little pyroxene present and considerable tridymite.

ART. XXVII.—*Cassiterite, Spodumene and Beryl in the Black Hills, Dakota;* by WILLIAM P. BLAKE.

CASSITERITE is found in place and in stream deposits in the central region of the Black Hills, Dakota, about two miles from Harney in Pennington County. This tin ore occurs in a vein, or mass, of coarsely crystalline granite rising through the fine-grained micaceous and siliceous slates of the Huronian period flanking the granitic axis of the Harney range of mountains.

At the principal point of discovery, known as the Etta claim, the feldspar quartz and mica are in unusually large crystals. Some of the cleavage blocks of feldspar measure from twelve to twenty inches across and the mica crystals have yielded sheets of commercial value. In addition to these minerals there is an abundance of spodumene in gigantic crystals ranging from two to six feet in length and from eight to twenty inches in diameter. The first masses of tin ore found were imbedded in the midst of the crystals of spodumene and of feldspar, and yielded fragments of nearly pure cassiterite weighing from one to fifty pounds and more. The chief associate or gangue of the tin ore is, however, a dense aggregation of small crystals of mica, of a light yellow color, forming irregular veins and bunches in the midst of the granitic mass. In this micaceous rock, formed of the mica with a white spar apparently albite, the tin ore is disseminated in grains from the size of a mustard seed to the size of peas, and sometimes an inch in diameter. These grains are irregular in form; no perfect crystals have yet been found. They can be easily separated from the mica by crushing and washing. The ore appears to be very clean; no wolfram has yet been found with it in the mica, but a few crystals of a black mineral, believed to be wolframite, have been seen in the mixture of spodumene and feldspar. No topaz has yet been identified.

At another locality where large plates of muscovite-mica have been mined, I have found beryls in large crystals, imbedded in a matrix of quartz, resembling the beryls found in the mica mines of Acworth, New Hampshire, though not so large.

ART. XXVIII.—*Discovery of a new Planetoid;* by C. H. F. PETERS. (Communication to the Editors, dated Litchfield Observatory of Hamilton College, Clinton, N. Y., Aug. 15, 1883.)

I TAKE pleasure in sending notice of a new planetoid that I fell upon in the night of August 12th. It is bright 9th magnitude. The following two observations are considered good, the positions of the comparison stars being well ascertained. The filar micrometer, bright wires in dark field, with a power of 270, was used.

1883.	m. t.		
	h. m. s.	h. m. s.	
Aug. 12,	13 49 28	α [234]=21 20 48·17	δ [234]= −12° 29′ 8·9″
14,	12 46 11	α [234]=21 19 40·44	δ [234]= −13 7 33·0

From the very strong motion in declination we may infer that the planet is comparatively near to the earth.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Hypothesis of Prout.*—GERBER has suggested a modification of the hypothesis of Prout, based upon the dynamic assumption that the atom is the result of an ether undulation. A primary undulation in this medium would produce secondary waves having relations with it analogous to those of sound vibrations. Representing one of the elements of the undulation, the velocity for example, by the atomic weight, the author has sought for harmonic relations between the atomic weights of different elements and has found that they may be divided into four classes, distinguished by the dominant valence of the elements which they contain, and each of which has a common divisor, in general greater than unity; so that the atomic weights of bodies of the same class are exact multiples of this common divisor by simple factors. For the first division or class the factor is 0·7673 or 0·76923, according as O is assumed as 15·96 or 16. For the second division 1·995 or 2. For the third division 1·5586 or 1·5625. And for the fourth division 1·246875 or 1·250. The relation between these factors and hydrogen—first pointed out to the author by Pliny Earle Chase—is given as follows: for O=15·96, $\alpha_1=\frac{1}{13}$H=0·7673, α_2=H or 2H=1·9950, $\alpha_3=\frac{2}{16}$H or $(\frac{5}{4})^2$H=1·5586, and $\alpha_4=\frac{5}{4}$H=1·246875. For O=16, the values are, of α_1

0·76923, of α_2 2·000 or 1·000, of α_3 1·5625 and of α_4 1·2500. Tables are given showing the accord between the calculated and the experimental atomic weights. The author concludes that there exists: (1) a common unit, in general greater than 1, between all the elements which belong to the same natural group; (2) simple ratios between the four common units, the multiples of which include all the atomic weights with an approximation as close as can be desired; and (3) simple relations between the weight of all the elements, distinct from those claimed by Prout. —*Bull. Soc. Ch.*, II, xxxix, 562, June, 1883. G. F. B.

2. *On a modified form of V. Meyer's Vapor density apparatus.* —SCHWARZ has substituted the ordinary combustion furnace for the special furnace employed by V. Meyer in determining the vapor density of substances of high boiling point. A trough of sheet iron a millimeter thick, having a close-fitting cover, is placed in the furnace. Two sloping sheets of iron cover the furnace, in place of the ordinary clay pieces. The trough has supports for the tube, and is lined with asbestus. This tube is closed at one end and has a capacity of 170–180 c.c. From its open end a rubber tube communicates with the collecting tube. The substance is introduced in a porcelain or platinum boat, or if liquid, in a bulb with a fine open point. In making a determination the tube is placed in the furnace with about 10 cm. projecting from the end, a cork ring preventing its being pushed back. A double screen of sheet iron is placed between the cork and the furnace. The tube is filled with dry nitrogen, the weighed substance is introduced at the cool end, the connections are made with the collecting tube, the furnace is tipped back so as to allow the boat to slide down the vaporizing tube, and is rested on a block. Soon bubbles of air enter the collecting tube and the process terminates in a minute or less. The water is leveled, the volume of air read, the thermometer and barometer noted and the vapor density calculated by V. Meyer's formula. Numerous examples of results obtained in this way are given. Anthracene 88·6, cal. 89·0; anthraquinone 105·1, cal. 104·0; ammonium chloride 13·67, cal. 13·375; triphenyl-methane 125·7, cal. 122·0, etc. The author has shown that soft paraffin has always a lower vapor density than hard; the former gave 57·2 corresponding to the formula C_5H_{18}; the latter 123·2, the formula $C_{17}H_{36}$ requiring 120.—*Ber. Berl. Chem. Ges.*, xvi, 1051, May, 1883. G. F. B.

3. *On a new Tellurium oxide, and on a new Reaction of Tellurium.*—DIVERS and SHIMOSÉ have obtained a new oxide of tellurium by heating in a vacuum the compound of sulphur trioxide and tellurium until it decomposes. It is a solid body which on heating decomposes into tellurium dioxide and free tellurium, the latter volatilizing before the former. The sulphoxide was heated in a tube retort in a paraffin bath, the tube being connected with a Sprengel pump. It fuses to a pasty mass, then decomposes, intumescing very much and evolving sulphur dioxide; its brown

color turns to the black of the new oxide which now resembles charred cork. The vesicular mass is rubbed to powder and washed with water containing a little sodium carbonate to remove sulphur compounds and tellurous acid; then with pure water and alcohol and dried. It is stable in ordinary dry air, is black in color with a brown shade, has a graphitic luster when pressed, has the formula TeO or a multiple of it, is decomposed by potassium hydrate on boiling, and by hydrochloric and sulphuric acids in the cold, is oxidized readily by nitric acid and colors sulphuric acid red as it dissolves in it, tellurous sulphate being deposited from the solution. It appears to have neither acidic nor basic properties. The authors have also prepared and critically examined tellurium sulphoxide, obtained by acting on tellurium with sulphur trioxide in a closed and exhausted tube. Heat is evolved and the loose gray tellurium passes into the bulky deep red sulphoxide. After digestion at 30°–40° the excess of SO_3 was drained off, the last portions being removed by exhaustion with a Sprengel pump the tube being heated to 35°. Thus prepared, tellurium sulphoxide is an amorphous solid, which softens at about 30° without melting; of a beautiful red color transparent in thin layers, quite stable when kept in closed tubes; having the formula SO_2Te; and decomposed by water into tellurium, tellurium monoxide, tellurous acid, sulphurous and sulphuric acid. It appears to exist in two modifications, the red variety being converted instantaneously into a brown substance at 90° which has identically the same composition. To the red modification the authors assign the formula $O\left\{\begin{matrix}Te\\|\\SO_2\end{matrix}\right.$; to the brown variety the formula $O\left\{\begin{matrix}TeO\\|\\SO\end{matrix}\right.$.

In a subsequent paper, Divers and Shimosé have described a new and delicate reaction for tellurium. When sulphuric acid holding in solution a minute quantity of tellurium dioxide is poured into a hydrogen apparatus, the escaping gas will contain hydrogen telluride. If now this gas is passed into the telluretted sulphuric acid the red color of tellurium sulphoxide is developed in the liquid. If the gaseous current be continued too long, the red sulphoxide is destroyed and a brown insoluble substance appears, sometimes in black scales with metallic luster, which is probably hydrogen pertelluride.—*J. Chem. Soc.*, xliii, 319, 323, 329, June, 1883. G. F. B.

4. *On the Production of Sulphides by Pressure.*—SPRING has continued his researches upon the production of chemical compounds by means of pressure and has now given the results of exposing various metals mixed with sulphur, both finely divided, to a pressure of 6500 atmospheres. Magnesium after six pressings, each time being reduced to filings, gave a homogeneous gray mass having a weak metallic luster. Mixed with water at 50° or 60°, hydrogen sulphide was evolved, the water becoming gold

yellow and giving a precipitate of sulphur on the addition of a drop of acid. Zinc after three pressings gave a sulphide resembling the natural blende, which dissolved slowly in dilute sulphuric acid evolving hydrogen sulphide. Iron gave after four pressings a block which was scarcely touched by the file and which appeared homogeneous under the microscope. It evolved steadily H_2S with sulphuric acid. When heated in a tube no further reaction took place, the mass slowly melting. Cadmium sulphide was formed easily in three pressings, the mass being homogeneous and yellowish gray. Bismuth sulphide was formed in two pressings, lead sulphide still more easily. Silver required six to eight pressings before the mass became homogeneous. Copper yielded the sulphide in three pressings and so also did tin. Antimony gave a grayish black sulphide in two pressings. It had the luster of antimony glance and dissolved in hot hydrogen chloride with the evolution of H_2S. Aluminum gave an imperfect result, as also did carbon. Both this latter body and red phosphorus formed hard blocks when pressed with sulphur which appeared like compounds but in which no phosphorus sulphide or carbon sulphide could be detected. From these results Spring draws the conclusion that allotropic states are but different conditions of polymerization, the chemical activity decreasing as the process goes on.—*Ber. Berl. Chem. Ges.*, xvi, 999, May, 1883.

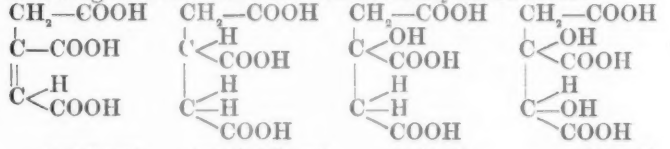
G. F. B.

5. *On Double Orthophosphates of Barium.*—Barium hydrate, as is well known, is quite soluble in concentrated solutions of the alkali silicates. DeSchulten has utilized this fact in the preparation of the double orthophosphates of barium, with sodium and with potassium. On adding a solution of potassium phosphate to a concentrated solution of potassium silicate containing barium hydrate, no change is at first observed; but on agitating strongly the liquid becomes milky and deposits microscopic cubes. To obtain larger crystals, the silicate solution is heated to boiling and a second silicate solution, containing the potassium phosphate, is added. On cooling, limpid cubical crystals are deposited. After rapid washing in cold water and drying, they dissolve easily in dilute hydrogen chloride, leaving a residue of silica amounting to about one per cent. Considering this as an impurity, analysis gives the formula $KBaPO_4$, $(H_2O)_{10}$ for this double phosphate. The crystals effloresce slightly in the air and do not act upon polarized light. By substituting sodium salts for those of potassium, sodio-barium orthophosphate is obtained in regular tetrahedrons, which are efflorescent and contain about two per cent of silica.—*Bull. Soc. Ch.*, II, xxxix, 500, May, 1883. G. F. B.

6. *On Saponin.*—Saponin was discovered in 1809 by Schrader in the root of *Saponaria rubra*. Stütz has submitted it to a thorough investigation in Geuther's laboratory. To prepare it ten kilograms of the bark of *Quillaja saponaria* was extracted with water, the liquid evaporated to a thick syrup, dried upon porcelain plates, pulverized, extracted with boiling alcohol, the

extract allowed to cool, and the separated flocks filtered off and redissolved in hot alcohol and again allowed to separate on cooling; the process being repeated till the deposited saponin was perfectly white. The yield was 200 grams. As thus prepared, saponin is a white amorphous powder, neutral in reaction, and when absolutely pure, tasteless. It is soluble in every proportion in water, insoluble in absolute alcohol and ether. The most dilute aqueous solutions froth like solutions of soap. It contains 2·4 per cent of ash, chiefly potassium, calcium and magnesium carbonates. Analysis led to the formula $C_{19}H_{30}O_{10}$. By adding barium hydrate to its aqueous solution, a precipitate was obtained having the formula $(C_{19}H_{30}O_{10})_2$, $Ba(OH)_2$. By treatment with acetic oxide, the saponin was acetylized giving either $C_{19}H_{25}(C_2H_3O)_5O_{10}$ or $C_{19}H_{25}(C_2H_3O)_5O_5(OC_2H_3O)_5$, according to the time of the action. From these reactions the author concludes: (1) that the formula of saponin is $C_{19}H_{30}O_{10}$; (1) that five of the oxygen atoms are in the form of hydroxyl and two in that of combined oxygen doubly united to the carbon. Of the nature of the other three no conclusion can be drawn. Hence the formula may be written $C_{19}H_{25}(OH)_5O_2.O_3$; (3) that by the action of the acetyl oxide, the five hydroxyls are first replaced by acetyl and subsequently the two oxygen atoms successively, are made linking and unite the acetyls to the carbon, as in the case of aldehyde and ethylene oxide.—*Liebig's Ann.*, ccxviii, 231, May, 1883. G. F. B.

7. *On a New organic acid in the Juice of the Beet Root.*—Von Lippmann has examined the incrustations formed upon the pans in which beet juice is evaporated. Beside citric, aconitic, tricarballylic, and malonic acids, he has now isolated a new acid, which was obtained by fractional solution in ether and evaporation. The resulting syrup after standing two years became a mass of needle-shaped crystals, soluble in water, alcohol and ether and having the formula $C_6H_8O_7$. The barium salt is $(C_6H_5O_7)_2Ba_3$, $(H_2O)_5$, the acid being tribasic. This acid appears to be identical with the oxycitric acid described by Pawolleck, prepared from chlorcitric acid, itself obtained from aconitic acid by union with hypochlorous acid; though Pawolleck could not obtain his acid crystallized and says his lime salt contains nine instead of ten molecules of crystal water. The author gives the following rational formulas to these closely allied acids:



Aconitic acid.	Tricarballylic acid.	Citric acid.	Oxycitric acid.
$C_6H_6O_6$	$C_6H_8O_6$	$C_6H_8O_7$	$C_6H_8O_7$

—*Ber. Berl. Chem. Ges.*, xvi, 1078, May, 1883. G. F. B.

8. *On the Silicic Ethers of the Phenols.*—MARTINI and WEBER have called attention to the facility with which the silicic ethers of the phenols may be prepared by heating silicon tetrachloride with on excess of the phenol. In this way they have obtained tetraphenyl orthosilicate $Si(OC_6H_5)_4$ and tetra-*p*-cresyl orthosilicate $Si(OC_7H_7)_4$. Both of these bodies may be distilled unchanged. The phenyl compound is syrupy when cold, and becomes slowly crystalline. The paracresyl ether is solid from the first and may be obtained beautifully crystallized. The authors propose to continue their researches upon these ethers.—*Ber. Berl. Chem. Ges.*, xvi, 1252, June, 1883. G. F. B.

II. GEOLOGY AND MINERALOGY.

1. *Report of an exploration of parts of Wyoming, Idaho and Montana, in August and September*, 1882, *made by Lieut.-Gen.* P. H. SHERIDAN, *with the Itinerary of Col.* J. F. GREGORY, *and a Geological and Botanical Report by Surgeon* W. H. FORWOOD. —In the geological report, Surgeon Forwood gives the results of observations showing that changes in the geyser action of the Yellowstone Park are in progress, and new geysers making at times their appearance. The following is from pp. 47, 48.

"The very careful observations of Dr. Peale in 1872 on the frequency, height, duration, etc., of the principal geysers in the upper basin, show no perceptible diminution of their power, as compared with the performances of these geysers at our visits in 1881 and 1882. The Castle, Bee-Hive, Old Faithful, Saw-Mill and Turban Geysers appear to perform just as they did ten years ago. The Grotto Geyser may have increased a little in frequency and diminished in duration, and the Grand and Giantess have changed somewhat in character and for the better, as will be seen by the following notes.

Grand Geyser.—Dr. Peale records the following observations in 1872:

August 18.—One continuous eruption, lasting 15 minutes.

August 19.—One continuous eruption, lasting 37 minutes.

August 20.—A succession of three eruptions, with intervals as follows: First eruption, three minutes; interval, six minutes. Second eruption, four minutes; interval, ten minutes. Third eruption, nine minutes. Total time, thirty-two.

Messrs. E. S. Dana and Grinnell (Ludlow's report) observed, August, 1875, a succession of *five* eruptions, with short intervals.

August 25, 1881.—There was a succession of *seven* eruptions, with short intervals, one to three minutes; total time estimated, thirty to forty minutes; and on the same day, two hours later, the same performance was repeated.

August 26.—A succession of seven eruptions, as before; not repeated that day.

August 19, 1882.—(Reported by eye-witnesses.) Geyser

played at 2 P. M., and again an hour later, giving a fine display of seven eruptions each time.

August 20.—A succession of seven eruptions, with intervals substantially same as last year, but not repeated.

August 21.—Same as yesterday.

It appears, then, that in 1872, the geyser often discharged at a single eruption, with occasional successions of as many as three. In 1875 there were a succession of five eruptions, and in 1881 and 1882 there were never less than seven observed, and these were not unfrequently repeated an hour or two later.

Giantess Geyser.—In 1872, as recorded by Dr. Peale (Hayden's report, p. 149), there were three eruptions of about seventeen minutes each, at intervals of three-quarters of an hour.

In 1875, as observed by Dana and Grinnell, the performance was as follows: After some preliminary efforts, during which a large amount of water was thrown out, there was an interval of two hours, when a similar disturbance took place, and two hours later the geyser played to a great height for about an hour, after which there was a violent escape of steam for an hour or more longer.

In 1882, as observed by Mr. John Baronett, the geyser began August 6, 8 P. M., and played twenty feet or more for about fifteen minutes; then followed an interval of about the same time; then it played twenty to fifty feet, with occasional sprays up to 150 feet for three-quarters of an hour, followed by an interval of about the same time. Continued to play with intermissions in same way up to midnight, and was still playing in morning and up to 12 M. August 7, when it ceased, and the crater was empty to a great depth.

August 13, 5.30 P. M., it began with a rumbling noise and shot up 'higher than Old Faithful,' and then varied between 20 and 150 feet for three-quarters of an hour, and an intermission of about the same time followed. Thus the eruptions and suspensions, about three-quarters of an hour each, continued throughout the 13th, 14th, and up to 9 o'clock on the morning of the 15th, when action ceased and the crater was empty as before.

A new geyser of the first class appeared about three years ago, in place of some hot springs, a short distance west of the Giant, called the Splendid, and well deserves the title. It has three jets, two directed obliquely inward and one vertical in the center, and plays to a height of fifty to seventy-five feet once in about two and one-half hours.

The Sheridan Geyser is another new one, situated on the Fire Hole River, about half way between the Upper and Lower basins, and is the largest in the park. It was one of a group of hot springs designated by Dr. Peale as the 'Half-way Springs' in 1872 (see Hayden's Report, 1872, p. 147). It began to play at irregular intervals, and, finally, within the last year, settled down to a constant period of about two hours. It was impossible at our hasty visit to obtain measurements or even correct estimates of the dimensions of the crater, owing to the dense clouds of

steam that constantly envelop it from sight, but while in eruption the column appeared to be about 200 feet in diameter and rose to a great height, accompanied by vibrations of the surrounding surface and the throwing out of rocks, which cover the ground and the bed of the river for a hundred yards on all sides. Its character as an eruptive geyser was first pointed out by the distinguished mountaineer, Mr. John Baronett, who named it in honor of General Sheridan in 1881."

2. *Report on the Thermal Springs of the Yellowstone National Park;* by A. C. PEALE. From the 12th Annual Report (for the year 1878) of the U. S. Geological and Geographical Survey under Dr. F. V. HAYDEN, U. S. Geologist-in-Charge. 454 pp. 8vo, with numerous maps and plates.—This Report is based mainly on observations in the Park made in the year 1878. But it includes also a review of the facts connected with other thermal springs in America, and with those of foreign countries. The descriptions of the springs and geysers of the Park make Part I of the volume; and they are accompanied by many illustrations which add greatly to the interest and value of the Report. Part II—covering pp. 304–354—treats briefly of the same phenomena in other countries and other parts of the United States, and Part III discusses the general subject of Thermo-hydrology, and consists largely of facts and views presented by other authors, but with a reference to the bearings on these views of the facts from the Yellowstone Park. This valuable Report closes with an extended bibliography, or list of papers on the Park and on American and foreign thermal waters.

The following notes are cited from its pages. The total number of springs in the Park is stated to be about 3000, and the number of ascertained geysers 62, besides 9 that are mentioned with a query. The following throw up the water to a height of 200 feet, or beyond: the Giant, 200; Castle, 200; Grand, 200; Giantess, 250, and Beehive, 230. The jet of Old Faithful is stated at 150 feet.

Bunsen's theory of the action of geysers is accepted (after a consideration of other views), as in the main sufficient. But there are differences in action among them which require special explanation. For example, in Old Faithful and Beehive, the action is simple, it consisting of a water eruption in successive jets that follow each other rapidly, without a succeeding period of steam emission; whereas in Castle Geyser, the type of another class, the water eruption is followed by a steam period of considerable length. In still others, under each of these divisions, the water period is broken into a number of water ejections, with varying intervals of minutes or hours, while the regular interval in the water periods is a day to several days.

The amount of silica found on analysis by Leffmann, in waters from the Yellowstone Geyser basins, varied from 53·76 grains in an Imperial gallon out of 143·22 grains of solid contents, to 3·36 grains out of 83·30 of solid contents; the former

at the Opal spring of the Gibbon Basin, the latter at the Mammoth Hot Springs. The water from the Opal spring, on concentration to a small bulk over a water bath, affords a gelatinous deposit which finally dries to a mass of pulverulent geyserite. Next to silica the most abundant material is sodium chloride (common salt) which at the Opal spring amounted to 82·18 grains in the gallon, while calcium salts are often wholly absent or only in traces. In most of the springs a deposition of silica does not take place on cooling, evaporation being necessary.

Besides the ordinary geyserite, which contains usually 9 to 13 per cent of water, (and the Pealite in which the water is 1 to 6 per cent), an unstable variety which, when still moist, makes an incrustation looking a little leathery, but dries to a soft, easily crumbling mass, is named, by E. Goldschmidt, *Viandite*. The "steam-dry" material was found to afford about 75 per cent of water to 20 of silica; but the describer says that "very probably the compound possesses no stability."

3. *On the cause of the Glacial Period;* by SEARLES V. WOOD (Geol. Mag., x, July, 1883, pp. 293–302).—The general conclusion of this paper is given on page 150. The following is a notice of the author's course of argument prepared for this Journal by Mr. W. J. McGee.

In this memoir, which embodies the cosmologic ideas developed during his extended researches in the Newer Pliocene of England, Mr. Wood reiterates and accepts as fatal to the eccentricity theory the correct arguments against repeated alternation of cold and warm intervals during the Quaternary, and assails Tyndall's dictum that general terrestrial refrigeration could not inaugurate glacial conditions. Also, following Dana in America, he shows that the traces of Quaternary ice-extension sustain a definite relation to present precipitation and temperature distribution; from which he infers, *first*, that the assumption of a polar ice-cap is an error, *second*, that all theories involving considerable geographical changes, alterations in the position of the terrestrial axis, or variations in the obliquity of the ecliptic, are alike invalid, and *third* (since the Gulf of Mexico in its present condition is the chief vapor-source of eastern North America), that Croll's position in regard to the Quaternary diversion of the Gulf Stream feeders is untenable. The prevailing theories thus disposed of, he points out that while a diminution of temperature will materially reduce the rainfall, it may not reduce, but may even increase the snowfall and annual ice-accumulation, and cites the present considerable ice-accumulation in Greenland, despite the low precipitation there, in proof of the soundness of his view; from which he concludes that the Quaternary ice was probably developed under lower temperatures than those now obtaining. In explanation of the assumed cooling of the earth during the Glacial period, he adopts the chemical theory of solar energy as advocated by Siemens and others, assumes that the heat-supplying material is irregularly diffused through the space traversed by the solar system, and supposes that solar emission is hence variable.

4. *Deep-sea Magnesian Limestone Nodules.*—Prof. Verrill, on page 447 of the last volume of this Journal, describes nodules or masses of limestone from a few inches to nearly thirty in length, dredged up on the Gulf Stream in depths of 234 to 640 fathoms. Science of August 10th gives an analysis of one—a hard, compact kind, sp. gr.=2·73—by Prof. O. D. Allen, as follows: lime 24·95 per cent, magnesia 14·41, iron (estimated as protoxide) 2·00, insoluble residue (sand) 16·97, phosphoric acid not weighed. It contained minute specks of pyrite.

III. Botany and Zoology.

1. *Genera Plantarum ad Exemplaria imprimis in herbariis Kewensibus servata definita.* Auctoribus G. Bentham et J. D. Hooker. Londini: Reeve & Co. 3 vols. imp. 8vo. 1852–1883. —The completion of this great work marks an era in systematic botany. As the senior author is nearly eighty-three years of age, we may say that, essentially, it brings to a worthy close the long course of scientific labors of the most accomplished, sagacious, and continuously industrious phytologist of our day, almost the only survivor of those who personally knew Antoine Laurent Jussieu, and were associated with the elder De Candolle; one whose line of authorship, begun in the year 1826 (antedated only by that of the venerable Roeper), comes down to the present year, apparently in almost unabated vigor, and is as remarkable for sustained importance as it is unparalleled in length. Upon the junior author, who should not yet feel the burden of years, however weighted with official cares, and upon such specialists as can be mustered, may devolve the responsibility of such *addimenta* as may be needed to bring the earlier volumes up to the date of the last, and even to supplement the work from time to time, as the "Genera Plantarum" of Linnæus was supplemented by successive editors. But it is not probable that the task which has now been happily accomplished will be undertaken again, still less executed, before the twentieth century is well entered upon. Useful compilations we may expect, and monographs which may here and there better represent advancing knowledge of particular groups; but a production like this, covering the whole field of phænogamous botany, ordinally and generically, and with the uniformity of treatment and scale thus secured by two close associates in one continuous work, cannot be looked for again for a long while.

It has few predecessors. The first "Genera Plantarum," in fact (though not exactly in name), was that of Tournefort, published in the year 1700. Then and there, as Linnæus declared, genera of plants, in the sense of scientific botany, were first established. There would probably be more recognition of this *dictum* if the present work were to be planned anew, and the genera which Linnæus himself admitted as of Tournefort, along with those which modern botanists have restored, could have been attributed to this real founder, without thereby compromising the proper

position to hold in respect to herbalistic and ancient names. The second "Genera Plantarum" was that of Linnæus, in 1737, of which the last edition revised by the author himself was that of 1767. The third was that of Jussieu, "secundum ordines naturales disposita," which appeared in the year 1789. That of Endlicher—a monument of literary or bibliographical erudition rather than of botanical research—was brought out in the main between 1836 and 1843, at about the same time with the more unpretending synoptical compilation of Meisner. These were important in their way. But the "Genera Plantarum" of Bentham and Hooker, which began to be issued in the year 1862 and was finished in the spring of the present year, is the lineal successor of the three classical works above mentioned, that of Tournefort representing the botany of the close of the seventeenth century; that of Linnæus the first half, and that of Jussieu the latter part, of the eighteenth century. The present work—increased from the one small octavo of Linnæus to three thick imperial octavo volumes of nearly 1,200 pages each—stands in like relation to the nineteenth century, and is based, like them, or even more than they, upon actual investigation, and upon the comparison of a vastly greater number of original types than was formerly possible.

Unlike its predecessors, however—and in this respect agreeing with the other great botanical work of the century, the "Prodromus" of De Candolle—the whole of cryptogamic botany is omitted. This vast field must be left to specialists. Fries, of Upsala, who died a few years ago, at a ripe old age, was the last phænogamic botanist who was at the same time master of one or two cryptogamic orders; and now even the best of cryptogamists can hardly aspire to more than a general and superficial acquaintance with any other department than the one to which he devotes himself. This inevitable state of things has its disadvantages. The reasons for it do not really apply to the ferns and their allies, and it was naturally expected, as it is much to be desired, that these should enter into the present work. May we hope that this still may be?

Some idea of the progressive enlargement of the field may be had by a comparison of the number of genera characterized in these successive works. The phænogamous genera of

Linnæus,	"Gen. Pl.,"	ed. 1, A. D. 1737,	were	887
"	"	ed. 6, A. D. 1764,	"	1,189
Jussieu,	"	A. D. 1789,	"	1,707
Endlicher,	"	A. D. 1843,	" (about)	6,400
Bentham & Hooker,	"	A. D. 1883,	"	7,585

If the last had been elaborated upon the scale of Endlicher, or with the idea of genera which is still common if not prevalent, the number of genera would have amounted to at least ten thousand. An estimate of the number of known species of each genus and higher group has been made throughout the work—a rough approximation only, mentioning first the number in the books, and the number to which, in the opinion of the authors, these may

probably be reduced by botanists who adhere to the Linnæan view of species; from which it appears that upon the very strictest estimate their number, as now known to botanists, is at least 95,620. In round numbers, it may fairly be said that about 100,000 species of phænogamous plants are in the hands of botanists. The five largest orders, as well for genera as for species, are the following, and in this rank: Compositæ, Leguminosæ, Orchideæ, Rubiaceæ, Gramineæ. The high standing of the orchid family in the list will be a surprise to many. Linnæus knew only a hundred species; five thousand is now a moderate estimate—about half as many as there are of Compositæ, which hold to their proportion of one-tenth of the whole. In both families every country and district is largely peculiar in its species and types. The far greater prominence of Compositæ over orchids is owing to the vast number of individuals in the former, their paucity in the latter.

Those who desire to know the respective parts which the two authors have taken in the elaboration of the "Genera Plantarum" may be referred to a short article on the subject in a recent number of the Journal of the Linnean Society of London. Great thanks from all botanists are due to them both.—(*Reprint from the Nation*, July 19, 1883.) A. G.

2. *Itinera Principum S. Coburgi* are published in princely style. We have before us the first volume of the Botany of the Travels of (1.) The Princes Philip and Augustus of Saxe-Coburg-Gotha round the world, in 1872–73, and (2.) The Visit to Brazil of the Princes Augustus and Ferdinand in 1879. Edited by Dr. H. Wawra von Fernsee, and published at Vienna in 1883. It is an imperial quarto volume of 182 pages, in beautiful typography, and with 39 charming lithographic plates, most of them hand-colored. The plants enumerated, and in case of new or critical ones described, are of various orders of Dicotyledones (but Compositæ omitted from this volume), and of the *Bromeliaceæ* among the *Monocotyledones*. To this order special attention is paid, and twenty of the plates are devoted to its illustration. The voyage and journey round the world was by way of New York and by the Central Pacific Railway to Utah and California, including the customary visit to the Yosemite and the Big Trees, thence to the Sandwich Islands, New Zealand, Australia, Ceylon, a turn to Japan, thence to Java, to India, Suez, and so to Trieste. We need not rehearse the itinerary of the subsequent Brazilian expedition. A second volume is to follow the first. The interest for us centers mainly in the *Bromeliaceæ* from Brazil, which are treated in detail, and interesting new forms figured; also in the small collection of North American plants, picked up *en route* across the Continent and in California. No new species are noted, but several give occasion for critical remarks or descriptions. A. G.

3. *Notice Biographique sur M. Joseph Decaisne*, par *Edouard Bornet*.—This very interesting and appreciative memorial was printed as a preface to the Catalogue of the Library of Professor

Decaisne, but is reprinted as a pamphlet of 19 pages, 8vo. It contains considerable information which we had not elsewhere met with, and is a worthy tribute to the memory of an admirable man and eminent botanist. A. G.

IV. Miscellaneous Scientific Intelligence.

1. *Supplementary note on the Bishopville Meteorite.* — Since the publication of my paper relating to the Bishopville and Waterville meteorites (this Journal for July), Professor C. U. Shepard, Sen., has called my attention to a foot note given in a paper of his entitled "Contributions to Mineralogy," and published at Amherst, Mass., in 1877.

In this note Professor Shepard claimed that his chladnite had "very erroneously been confounded with bronzite;" and that "it now seems probable that the blue substance [iodolite] was some spontaneously decomposable compound of S with other elements of the stone. The same may have been the case with the yellow mineral [apatoid] therein detected." M. E. W.

Cambridge, Mass., July 23, 1883.

2. *Lectures delivered [free] to the employés of the Baltimore and Ohio Railroad Company;* by Professor H. Newell Martin and Drs. Henry Sewall, Wm. T. Sedgwick and Wm. K. Brooks, of the Johns Hopkins University. 98 pp. 8vo. Baltimore, 1882.—These four lectures are thorough in their scientific character and, at the same time, well adapted by clearness in style and illustration to the audience to which they were delivered. A more scientific audience might have profited by them. The subjects are: How skulls and backbones are built; How we move; On Fermentation; Some curious kinds of Animal locomotion. The pamphlet was printed at the expense of President John W. Garrett, of the Railroad Company, for free distribution among the employés of the road, and "copies can be secured by written or personal application at the President's office in Baltimore."

3. *The Iroquois Book of Rites.* Edited by Horatio Hale, M.A., author of the Ethnography and Philology of the Wilkes U. S. Exploring Expedition, etc. 222 pp. 8vo. Philadelphia, 1883 (D. G. Brinton).—This important contribution to American history before the time of Columbus, and to the science of human progress, is by a man of wide learning and careful research, after special investigations among the Indians of the Iroquois tribe at the reservations in Canada and New York. It constitutes vol. ii of the "Library of Aboriginal American Literature."

4. The meeting of the *American Association* opened on Wednesday, the 15th of August. As the sessions are still in progress while these pages are printing, a notice of its proceedings is necessarily deferred.

Memoir of Louis Agassiz, by Arnold Guyot. 50 pp. 8vo, 1883. Read before the National Academy of Sciences.—An admirable memoir by one who was a companion of Professor Agassiz from his childhood, in the Neufchatel University, and in the decision to leave the University and Switzerland for the freer land of America.